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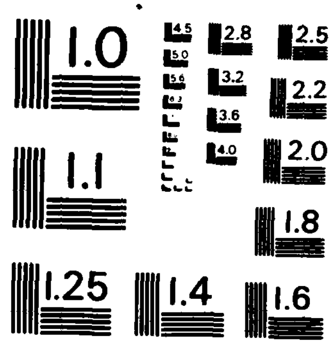

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POTENTIAL APPLICATIONS OF MULTIPLE INSTRUMENT APPROACH CONCEPTS AT 101 U.S. AIRPORTS

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16. Abstract

Concepts for conducting multiple IFR Approaches to airports include:

1. Independent and Dependent parallel approaches at reduced runway separations.

2. Converging approaches to non-intersecting and to intersecting runways.

3. Triple arrival streams to parallel and non-parallel runways.

4. The application of these concepts to the use of separate short runways and segregated traffic streams.

This report summarizes a survey of 101 U.S. Airports to determine potential applications of the above concepts. The survey identified many potential applications of each of the concepts using existing runways:

1. Parallel approaches - 25 airports;
2. Converging approaches - 74 airports;
3. Triple approaches - 6 airports; and
4. Use of separate short runways - 60 airports.

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The authors wish to thank James Mottley and George Bolduc of the Federal Aviation Administration for their assistance in conducting a survey of all of the FAA Regional Offices.

EXECUTIVE SUMMARY

BACKGROUND

The Federal Aviation Administration (FAA) has long recognized the problems of inadequate airport capacity and increasing delays. The report of the Air Traffic Control Advisory Committee (ATCAC) in 1969 concluded that the critical capacity problem was typically in the arrival process during Instrument Flight Rules (IFR) conditions. ATCAC recommended that capacity be increased by finding a method to decrease the minimum separation between aircraft on final approach during IFR conditions.

During the 1970's several concepts were developed to allow either reduced separations or multiple arrival streams to an airport. These were reviewed by FAA and industry representatives.

In 1982 The Industry Task Force on Airport Capacity Improvements and Delay Reduction led by the Airport Operators Council International (AOCI), recommended that the concepts for conducting multiple instrument approaches be implemented as soon as acceptable procedures could be demonstrated. Work has been underway to demonstrate those concepts at selected airports.

The concepts being demonstrated by the FAA include IFR procedures for parallel approaches, converging approaches, triple approach streams, and the use of separate short runways.

PURPOSE OF STUDY

An earlier study of 101 U.S. airports determined the potential benefits of applying these multiple arrival stream concepts and provided a listing of potential applications which included at most one application for each of the concepts at each airport. The main purpose of the present study was to revise that list of applications, to expand it to include all of the potential applications of each concept at each airport, and to take into consideration site-specific factors that may affect the applicability of the concepts. The task of evaluating site-specific factors was performed with the aid of responses to a questionnaire that was sent to each of the FAA regional offices. This questionnaire included questions related to site-specific

obstacles, restrictions, runway geometries, etc. In some regions the response to the questionnaire was much more detailed and complete than in others.

This survey analyzes 101 airports. These airports were selected to include the busiest airports ranked by number of total aircraft operations excluding those airports with very little or no air carrier traffic. Three airports (Denver Centennial (Arapahoe County), Spirit of St. Louis, and Seattle's Boeing Field), were included because they are among the 40 airports selected for capacity/delay task force studies. This list of 40 airports was proposed by the FAA offices of Airports (APP-400) and Air Traffic (ATO-400).

In addition to the "40 selected" airports mentioned above, the FAA has designated 22 airports as "pacing" airports. The airports selected are those among the top 101 ranked by air carrier traffic including all the airports listed in the "40 selected" and the "22 pacing" airports. In all cases, the applications identified involve the use of existing concrete.

The delay savings obtainable with the implementation of the concepts were estimated for a representative group of airports as an example of the potential benefits.

DESCRIPTION OF CONCEPTS

The concepts considered in this study deal with procedures for Category I approaches (Decision Height no less than 200 feet) to various runway geometries. All of the concepts utilize multiple approach streams. Requirements and procedures have been developed in several previous reports.

Independent Parallel Approaches at Reduced Centerline Spacing:

At the present time, independent approaches may be made to parallel runways (less than 15 degrees deviation from parallel is considered parallel) under the following conditions:

1. Runways are at least 4300 feet apart;

2. ILS, radar and two-way communications are required;

3. Aircraft are separated by a minimum of 1000 feet vertically or 3 nmi horizontally on radar until established on their respective localizer courses; and

4. Two monitor controllers ensure lateral separation between aircraft and intercede in the event of a blunder.

Decreasing the required runway separation to as little as 3000 feet for independent arrivals can most likely be achieved with an improved radar system (1 milliradian azimuth accuracy, 1 second update). The gain in capacity results from the treatment of arrivals as two independent streams.

Parallel runways are included in the survey and labeled "independent" if the spacing between them is at least 3000 feet and less than 4300 feet and the runways are at least 100 feet wide.

Dependent Parallel Approaches at Reduced Centerline Spacing:

At the present time, dependent alternating arrivals with a 2.0 nmi diagonal separation may be conducted to runways spaced as close as 2500 feet apart. For spacing below 2500 feet, the need for protection from the effects of wake vortices dictates diagonal separation that varies by size of aircraft.

The new concept of dependent parallel approaches extends the use of 2.0 nmi diagonal separation to runways as close as 1000 feet apart. This is felt to be potentially feasible for the following reasons:

1. An analysis of such dependent parallel approaches has shown that, if one arrival should blunder towards the other approach, the minimum miss distance after the controller acts is greater at smaller runway spacings. Blunders are therefore not a critical obstacle to reducing the runway spacing.

2. At spacings below 2500 feet, wake vortex is currently a problem. However, a recent study indicated that a combination of multiple glide slope angles, runway threshold stagger, and minimum headwind and crosswind values can be used to keep aircraft away from the vortices produced by larger aircraft on the other approach. This presents the possibility that the wake vortex problem can be overcome. No attempt has been made in this survey to analyze each configuration to determine the actual glide slope angles, headwinds or crosswinds which would be required, or the percentage of the year such operation would be feasible.

Parallel runways are included in the survey and labeled "dependent" if the spacing between them is at least 1000 feet and less than 3000 feet.

Dependent and Independent Approaches to Converging Runways:

For the purposes of this study the Terminal Instrument Procedures (TERPS) definition of "converging" is accepted: converging runways must have an included angle greater than 15 degrees. Two runways that diverge by more than 100 degrees are unlikely to be used together because of the effect of wind -- if there is a headwind on one runway, there would probably be a tailwind on the other.

There are three general categories of converging approaches:

1. Intersecting Approach Streams

Converging approaches in which the final approach paths intersect would be difficult to operate safely during any condition. There is little precedent for this operation during VFR conditions. Such geometries were not considered feasible for converging IFR operations and no examples are included in the survey.

2. Intersecting Runways

Independent operations on converging runways that intersect pose two kinds of problems:

a. The possibility of collision between two aircraft on that portion of each runway in which the pavement is shared; and

b. The possibility of collision during simultaneous missed approaches.

Neither problem would necessarily prevent the independent operation of intersecting runways. The process of holding short before the intersection is practiced at several major airports (e.g., Chicago O'Hare) and can possibly be employed at other runway geometries with at least one long runway. The missed approach problem can also be resolved. By requiring alternating, nonsimultaneous landings on the runways (called Dependent Converging Approaches), these two problems can be avoided with the penalty of smaller capacity gains then those achievable with independent operations.

3. Converging Runway (Extended) Centerlines

Those runways in which the extended centerlines intersect, or a variation in which the extended centerline of one runway intersects the other runway, present only the problem of simultaneous missed approaches. Because this category is the least complex, such an application of the converging concept is preferred.

This study considers two categories of converging approaches:

1. Dependent approaches to intersecting runways, or to nonintersecting runways on which simultaneous landings are not permitted; and

2. Independent approaches to favorable nonintersecting runways, or to intersecting runways with "hold-short" procedures.

The selection criteria used in this survey of converging runways are:

1. Independent Converging Approaches - runways must be nonintersecting, or intersecting with one runway having at least 8400 feet from threshold to intersection, to allow hold-short operations by all aircraft. Runways must meet preliminary requirements for IFR independent converging approaches.

2. Dependent Converging Approaches - intersecting or nonintersecting runways that could not meet the above requirements for independence. The available runway length on one runway must be at least 6000 feet, and 4000 feet on the other. Available runway length is the distance from threshold to runway end, or threshold to intersection if hold-short procedures are required.

Triple Approaches:

A logical combination of the first three concepts could result in the use of three runways simultaneously. Currently, no airport has three parallel runways, each 4300 feet apart; therefore, any triple configuration using existing pavement would include either one closely-spaced pair or one converging pair of runways. Three types of triple parallel approaches are considered:

1. Dependent/Dependent - the pair of approaches to the Center and Right runways are dependent, as are the approaches to the Center and Left runways. However, approaches to the Right and Left runways are independent of each other (this is true for all three types of triple approaches).

2. Independent/Dependent - approaches to the Center runway are independent of one runway, but dependent on the other.

3. Independent/Independent - approaches to the Center runway are independent of approaches on both the Right and the Left runways.

Triple runway configurations were selected only if one of the adjacent pairs of the triple met the conditions for independent parallel or independent converging operations.

Separate Short Runways:

The concept of separate short runways involves the use of segregated traffic to relieve the demand on the main runway by using a short runway which would have a length of 4000 feet to 6000 feet and need not be built to accommodate the weight of large aircraft. The short runway could be a parallel, converging or a third runway to be used simultaneously with the main runway. If the short runway intersects with the main air carrier runway, then there must be sufficient distance from the threshold to the intersection to allow "land and hold-short" operations.

The selection criterion for including a separate short runway in this survey was only that its length be between 4000 feet and 6000 feet. As it turned out, all but three of the potential applications involve converging runways, most of which intersect with the main runway.

RESULTS OF STUDY

Table 1 shows all the potential applications of each concept at each of the 101 airports. The airports are listed in rank order by number of aircraft operations. Listed in this table under each concept are the pairs of runways (three in the case of triples approaches) to which multiple instrument approaches are proposed.

TABLE 1
SUMMARY OF CONCEPT APPLICATION TO 101 AIRPORTS

AIRPORTS	DEPENDENT PARALLELS	INDEPENDENT PARALLELS	DEPENDENT CONVERGING	INDEPENDENT CONVERGING	TRIPLES	SEPARATE SHORT RUNWAYS
1. Chicago (ORD)				22R,27L 32L,27R 9L,4R 9R,4R 9R,14L	9L,9R,4R 27L,27R,22R 22L,22R,14R	
2. Atlanta (ATL)	8L,8R (1000') 9L,9R (1000')				8,9R,9L	
3. Los Angeles (LAX)----------	----------	----------	----------	----------	----------	----------
4. Denver (DEN)	17R,17L (1600')			17L,26L		
5. Dallas Ft. Worth (DFW)				35L/R,31R 36L/R,31R	36L/R,35L/R,31R	
6. Oakland (OAK)	27L,27R (1000')			29,27L 29,27R		29,27R
7. San Francisco (SFO)			10L,1R 28R,1R			10L,1R 28R,1R
8. St. Louis (STL)	30R,30L (1300')		24,30L	24,30R		24,30L
9. New York (JFK)		4R,4L (3000')	13L,4L	13R,22L 13L,4R		
10. Phoenix (PHX)		8R,8L (3400') 26R,26L (3400')				
11. Miami (MIA)			12,9R	27R,30		
12. New York (LGA)			4,31 13,4			4,31 13,4
13. Boston (BOS)	22R,22L (1500')		4R,33L			4R,33L
14. Houston (IAH)				26,32R		
15. Washington (DCA)			36,33			
16. Honolulu (HNL)			8L,4R			8L,4R
17. Philadelphia (PHL)	9L,9R (1400')		9L,17	17,9R		9L,17

TABLE 1
(Continued)

	AIRPORTS	DEPENDENT PARALLELS	INDEPENDENT PARALLELS	DEPENDENT CONVERGING	INDEPENDENT CONVERGING	TRIPLES	SEPARATE SHORT RUNWAYS
18.	San Jose (SJC)						
19.	Pittsburgh (PIT)	10R,10C (1200')		14,10C 14,10R		10L,10C,10R	10R,14
20.	Houston Hobby (HOU)			17,22 22,31L			17,22 22,31L
21.	Dallas Love (DAL)	31L,31R (2975') 13R,13L (2975')					
22.	Minneapolis (MSP)		11R,11L (3380') 29R,29L (3380')	22,29L			29L,22
23.	Las Vegas (LAS)			19R,25			25,19R
24.	Memphis (MEM)		36L,36R (3400') 18L,18R (3400')	21,27	36L,27 36R,27 36R,3 21,18R		21,27
25.	Charlotte, NC (CLT)			5,36R	18R,23		5,36R
26.	Salt Lake City (SLC)		16L,16R (3500')		14,16L 34L,32		14,16L 34L,32
27.	Tampa (TPA)			27,18L	27,18R		27,18L
28.	Detroit (DTW)	3C,3R (2000')	3L,3C (3800')		3R,9 21R,27	3R,3C,3L	
29.	Newark (EWR)			11,4R	11,4L		
30.	Baltimore (BWI)			15R,10 15R,22 33L,28			15R,10 15R,22 33L,28

TABLE 1
(Continued)

	AIRPORTS	DEPENDENT PARALLELS	INDEPENDENT PARALLELS	DEPENDENT CONVERGING	INDEPENDENT CONVERGING	TRIPLES	SEPARATE SHORT RUNWAYS
31.	Fort Lauderdale (FLL)		27L,27R (4000') 9L,9R (4000')	27R,31			27L,27R 9L,9R 27R,31
32.	Tucson (TUS)----------						
33.	Columbus (CMH)	10L,10R (2800')			31,28R 5,10L		28R,31
34.	West Palm Beach (PBI)			13,9L			9L,13
35.	Tulsa (TUL)			17R,26			17R,26
36.	Anchorage (ANC)				14,6R		
37.	Chicago Midway (MDW)----------						
38.	Albuquerque (ABQ)----------						
39.	San Antonio (SAT)			12R,21			12R,21
40.	Cleveland (CLE)			10L,5R 10L,5L			10L,5L 5R,10L
41.	Seattle (SEA)----------						
42.	Portland (PDX)		28L,28R (3100')	10R,2 28L,2			2,28L
43.	Birmingham (BHM)----------						
44.	Nashville, TN (BNA)	2L,2R (1800')		2L,31			31,2L 31,2R
45.	Daytona Beach (DAB)			16,6L			16,6L
46.	Fresno (FAT)----------						

TABLE 1
(Continued)

	AIRPORTS	DEPENDENT PARALLELS	INDEPENDENT PARALLELS	DEPENDENT CONVERGING	INDEPENDENT CONVERGING	TRIPLES	SEPARATE SHORT RUNWAYS
47.	Providence (PVD)	5L,5R (1700')		34,5R 28,34			34,5R 28,34
48.	Austin, TX (AUS)			35L,31L			31L,35L
49.	Burbank (BUR)			7,15			7,15
50.	El Paso, TX (ELP)	26L,26R (1200')			22,26R		22,26L 22,26R
51.	Grand Forks, ND (GFK)			26,35			26,35
52.	Raleigh (RDU)			32,5			32,5
53.	St. Petersburg (PIE)			22,17L 4,9			22,17L 4,9
54.	Indianapolis (IND)			4L,31 13,4L			4L,31 13,4L
55.	New Orleans (MSY)				10,19		
56.	San Juan, PR (SJU)				25,28		
57.	Wichita (ICT)				14,19L		
58.	Norfolk (ORF)			23,14			14,23 32,23
59.	Sarasota (SRQ)						
60.	Des Moines (DSM)			12L,5			5,12L
61.	Milwaukee (MKE)	1L,1R (1000')		7R,1L	13,7R		13,7R
62.	Cincinnati (CVG)	27R,27L (1700')		27L,36 18,27L			36,27L 18,27L

TABLE 1
(Continued)

AIRPORTS	DEPENDENT PARALLELS	INDEPENDENT PARALLELS	DEPENDENT CONVERGING	INDEPENDENT CONVERGING	TRIPLES	SEPARATE SHORT RUNWAYS
63. Buffalo (BUF)			14,5			14,5
64. Oklahoma City (OKC)				12,17L		
65. Orlando (MCO)	18L,18R (1600')					
66. Washington Dulles (IAD)				12,19L 12,19R	12,19R,19L	
67. Baton Rouge (BTR)----						
68. Little Rock (LIT)				18,22		18,22
69. Richmond Byrd Intl. (RIC)				2,33 20,24		15,6 33,6
70. Boise (BOI)----						
71. Madison, WI (MSN)			36,31	18,22		36,31 18,22
72. Kansas City (MCI)				19,27		
73. Albany (ALB)			28,1			28,1
74. Reno (RNO)			16,25			25,16 7,16
75. Dayton (DAY)			18,24L	6L,36		18,24L
76. Omaha (OMA)	32L,32R 14R,14L		17,14R			17,14R 32L,32R 14R,14L
77. Syracuse (SYR)			14,10			10,14
78. Louisville, KY (SDF)			29,24			29,24 6,1
79. Windsor Locks (BDL)						24,33 6,1
80. San Diego (SAN)----						

TABLE 1
(Concluded)

	AIRPORTS	DEPENDENT PARALLELS	INDEPENDENT PARALLELS	DEPENDENT CONVERGING	INDEPENDENT CONVERGING	TRIPLES	SEPARATE SHORT RUNWAYS
81.	Fairbanks (FAI)------	------	------	------	------	------	------
82.	Jacksonville (JAX)				31,25		
83.	Greensboro, NC (GSO)			23,14			14,23 32,23
84.	Manchester, NH (MHT)			35,6			35,6
85.	Charleston, SC (CHS)			33,3			33,3
86.	Corpus Christi (CRP)				13,17		13,17
87.	Rockford, IL (RFD)			36,6 18,12			36,6 18,12
88.	Grand Rapids, MI (GRR)------	------	------	------	------	------	------
89.	Billings, MT (BIL)			34,27R	16,22		16,22 34,27R
90.	Burlington (BTV)------	------	------	------	------	------	------
91.	Knoxville, TN (TYS)	5L,5R (1200')					5L,5R
92.	Lansing (LAN)------	------	------	------	------	------	------
93.	Kahului, Hawaii (HOG)			5,2			5,2
94.	Lubbock TX (LBB)						17R,26 35L,26
95.	Niagara Falls, NY (IAG)			28R,32 10L,6			28R,32 10L,6
96.	Sacramento (SMF)------	------	------	------	------	------	------
97.	Ontario (ONT)			21,26L 21,26R			21,26L 21,26R
98.	Akron Canton, OH (CAK)						14,19
99.	Boeing Field (BFI)------	------	------	------	------	------	------
100.	Centennial, CO (APA)------	------	------	------	------	------	------
101.	Spirit of St. Louis (SUS)------	------	------	------	------	------	------

EVALUATION OF DELAY SAVINGS FOR A REPRESENTATIVE GROUP OF AIRPORTS

A representative sample of airports was selected to study each of the different applications of the concepts listed in Table 1 for the purpose of illustrating the estimated benefits of implementation. These benefits are expressed in terms of delay savings, i.e., the amount of hours of delay saved during IFR conditions by shifting from the best current airport configuration to one of the multiple approach procedures.

The reductions in delays are a function of improvement in capacity as a result of concept implementation, the level and pattern of demand at each airport, and the percentage of IFR conditions.

The steps followed to calculate delays were:

1. The capacity of each airport was calculated (using the FAA Airfield Capacity Model) for the applicable concepts analyzed.

2. A daily demand profile (the number of arrivals in each of the 24 hours) was constructed for each airport based on the number of scheduled and general aviation operations.

3. The capacity values and the demand profiles were used as an input to an analytical model that calculated the total daily delay.

Table 2 presents the estimated daily delay savings.

SUMMARY AND CONCLUSIONS

At a number of airports, issues such as the lack of landing aids and airspace restrictions must be resolved as a prerequisite for concept application.

20 airports showed no potential for application of any of the concepts. Of the 101 airports studied in this report, the following number of airports were found to be potential candidates for the application of each concept using existing runways:

1. Parallel approaches at reduced runway spacing are proposed at 25 airports. Note that some airports have both dependent and independent parallel applications.

    a. Dependent parallel approaches: 18 airports.
    b. Independent parallel approaches: 8 airports.

TABLE 2
SUMMARY OF DELAY SAVINGS[1]

Airport	Concept to be used	Estimated Delay Savings (Hrs/Day)
Boston (BOS)	Dependent Parallels	259
Philadephia (PHL)	Dependent Parallels	44
Memphis (MEM)	Independent Parallels	6[2]
New York (JFK)	Independent Parallels	37[2]
New York (JFK)	Dependent Converging	26[2]
Newark (EWR)	Dependent Converging	209
Houston (IAH)	Independent Converging	121
Newark (EWR)	Independent Converging	212
Dallas-Fort Worth (DFW)	Triple Approaches	16[3]

1 - Arrival delays (assuming at least 50% of all operations are departures).

2 - Assumes Dependent Parallels as current configuration. Delay savings over single runway configuration are substantially larger.

3 - Assumes Independent Parallels as current configuration. Delay savings over single runway configuration are substantially larger.

2. Converging approaches are proposed at 74 airports. Note that some airports have both dependent and independent converging applications.

a. Dependent converging approaches: 52 airports.
b. Independent converging approaches: 32 airports.

3. Triple approaches are proposed at 6 airports.

4. Separate short runway usage is proposed at 60 airports.

Estimates of potential benefits at selected airports indicate that there are significant delay reduction benefits to be achieved by applying these concepts.

This survey restricted itself to potential applications of the concepts to existing runways. Once the concepts are accepted, there may be many airports which can increase their capacity by building new runways or lengthening existing runways to utilize these new multiple instrument approach procedures.

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1. INTRODUCTION

1.1 Background

The Federal Aviation Administration (FAA) has long recognized the problems of inadequate airport capacity and increasing delays. The report of the Air Traffic Control Advisory Committee (ATCAC) in 1969 (Reference 1) concluded that the critical capacity problem was typically in the arrival process during Instrument Flight Rules (IFR) conditions. ATCAC recommended that capacity be increased by finding a method to decrease the minimum separation between aircraft on final approach during IFR conditions.

Similar problems were noted in an FAA report to the Congress in 1974 (Reference 2) which concluded that:

1. "Delays are down from the peak (1969-70 levels, but) they remain undesirable and substantial increases may be expected in the future if improvements to the system are not instituted."

2. "Operational changes can provide additional capacity to meet adverse conditions such as severe weather and uneven traffic loads."

As a follow-up to the 1974 report, the FAA created specific Airport Capacity Improvement Task Forces to assess the effects of various technologies on airport capacity and delays. These studies were completed at Chicago, Denver, Los Angeles, Atlanta, New York Kennedy and La Guardia, Miami, and San Francisco. All of the analyses indicated a need for long term, major increases in capacity.

In 1982 The Industry Task Force on Airport Capacity Improvements and Delay Reduction led by the Airport Operators Council International (AOCI), recommended that the concepts for conducting multiple instrument approaches be implemented as soon as acceptable procedures could be developed. Work has been underway to demonstrate those concepts at selected airports.

In the meantime, major airports in the U.S. continued to experience increases in traffic. Annual airline delay costs now exceed $2 billion (Reference 3). The expected rise in fuel costs will further increase this delay cost. Furthermore, traffic growth may lead to disproportionate increases in delay costs, especially where demand already approaches or exceeds current capacity.

The following improvements can help to alleviate the shortage of airport capacity (Reference 4):

1. Terminal Automation -- automation aids for terminal controllers to increase the precision of delivery of aircraft to the runway.

2. Wake Vortex Sensing Systems -- devices to detect vortex transport and decay in order to identify conditions where IFR in-trail spacings may be safely reduced.

3. Microwave Landing Systems -- advanced approach navigation used to provide noise abatement and operational route separation for high capacity operations.

4. Airport Surface Traffic Management Systems -- new surveillance techniques and data processing to improve IFR ground control.

5. New airports and air carrier runways.

Although each of these options could be effective in increasing capacity, there are barriers to their application. Most of the candidate solutions require a large capital investment. Major additions of new airports or air carrier runways are considered unlikely before the year 2000 (Reference 5). Some of the technologies cannot be applied universally because of the investment cost. Some technologies have not yet been developed and/or tested under actual conditions. In order to achieve any capacity benefit from these five technologies, the FAA must first modify current procedures to permit multiple IFR approaches to closely spaced parallel or converging runways. The FAA has been studying five concepts for new IFR procedures. These concepts, which will be described in section 2, include (Reference 6):

1. Dependent parallel approaches at reduced centerline spacing;

2. Independent parallel approaches at reduced centerline spacing;

3. Dependent and independent approaches to converging runways;

4. Triple approaches; and

5. Separate short runways.

An earlier study (Reference 7) examined the top 101 airports to determine the potential benefits of applying these concepts. The results of that study showed that there were substantial benefits to be gained if the concepts were accepted and implemented. Since then, progress has been made and it now seems likely that the technique for conducting converging approaches will soon be adopted as an acceptable procedure. In 1983 the FAA modified its standards to allow dependent approaches to runways separated by 2500 feet. Active demonstration programs are underway that will lead to the acceptance and implementation of reduced longitudinal spacings of 2.5 nmi, parallel IFR approaches at reduced spacings and possibly triple approaches.

1.2 Purpose and Overview of Study

Congestion and delays at airports continues to increase. One way to alleviate such problems is to take steps toward the implementation of these multiple arrival stream concepts. In order to do so, it is necessary to determine all of the potential applications on a site-specific basis.

The earlier study of 101 U.S. airports (Reference 7) that determined the potential benefits of applying multiple arrival stream concepts provided a listing of potential applications which included at most one application for each of the concepts at each airport. The main purpose of the present study was to revise that list of applications, to expand it to include all of the potential applications of each concept at each airport, and to take into consideration site-specific factors that may affect the applicability of the concepts. The task of evaluating site-specific factors was performed with the aid of responses to a questionnaire that was sent to each of the FAA regional offices. This questionnaire included questions related to site-specific obstacles, restrictions, runway geometries, etc. In some regions the response to the questionnaire was much more detailed and complete than in others.

A brief description of each of the multiple arrival stream concepts is given in section 2. Section 3 provides the complete list of potential applications at 101 U.S. airports that were identified by this survey. Section 4 presents examples of the delay savings obtainable at a group of representative airports with the application of each of the multiple arrival stream concepts.

2. DESCRIPTION OF CONCEPTS AND CRITERIA FOR INCLUSION

The concepts examined in this study deal with procedures for Category I approaches (200 foot Decision Height) to various runway geometries. All of the concepts utilize multiple approach streams. Four of the five are tailored to particular runway geometries:

1. Dependent parallel approaches with reduced runway spacing;

2. Independent parallel approaches with reduced runway spacing;

3. Converging approaches; and

4. Triple approaches.

These concepts will be described below. A fifth concept, separate short runways for general aviation and air taxi/commuters, can be applied with any of the first four. This concept takes advantage of the efficiency of specialization by segregating traffic streams into air carrier (requiring long runways) and other traffic requiring shorter runways by virtue of their lower approach speed and lighter weight.

These concepts may be applied to new or existing runways. Since it is unlikely that a new runway would be constructed on the premise that an untried new concept could be utilized, initial implementation of the above concepts depends on their usefulness when applied to existing runways. Consequently this report restricts itself to existing runways and runways that have already been proposed.

2.1 Independent Parallel Approaches

At the present time, independent approaches may be made to parallel runways (less than 15 degrees deviation from parallel is considered parallel) under the following conditions:

1. Runways are at least 4300 feet apart;

2. ILS, radar and two-way communications are required;

3. Aircraft are separated by a minimum of 1000 feet vertically or 3.0 nmi horizontally on radar until established on their respective localizer courses; and

4. Two monitor controllers ensure lateral separation between aircraft and intercede in the event of a blunder.

Decreasing the required runway separation to as little as 3000 feet for independent arrivals can most likely be achieved with an improved radar system (1 milliradian azimuth accuracy, 1 second update -- Reference 8). The gain in capacity results from the treatment of arrivals as two independent streams.

Parallel runways are included in the survey and labeled "independent" if the spacing between them is at least 3000 feet and less than 4300 feet and the runways are at least 100 feet wide.

2.2 Dependent Parallel Approaches

At the present time, dependent alternating arrivals with a 2.0 nmi diagonal separation may be conducted to runways spaced as close as 2500 feet apart. For spacing below 2500 feet, the need for protection from the effects of wake vortices dictates diagonal separation that varies by size of aircraft.

The new concept of dependent parallel approaches extends the use of 2.0 nmi diagonal separation to runways as close as 1000 feet apart (Reference 8). This is felt to be potentially feasible for the following reasons:

1. An analysis of such dependent parallel approaches has shown that, if one arrival should blunder towards the other approach, the minimum miss distance after the controller acts is <u>greater</u> at smaller runway spacings. Blunders are therefore not a critical obstacle to reducing the runway spacing.

2. At spacings below 2500 feet, wake vortex is currently a problem. However, a recent study (Reference 9) indicates that a combination of multiple glide slope angles, runway threshold stagger, and minimum headwind and crosswind values can be used to keep aircraft away from the vortices produced by larger aircraft on the other approach. This presents the possibility that the wake vortex problem can be overcome. No attempt has been made in this survey to analyze each configuration to determine the actual glide slope angles, headwinds or crosswinds which would be required, or the percentage of the year such operation would be feasible.

Parallel runways are included in the survey and labeled "dependent" if the spacing between them is at least 1000 feet and less than 3000 feet.

2.3 Converging Approaches

For the purposes of this study the Terminal Instrument Procedures (TERPS, Reference 10) definition of "converging" is accepted: converging runways must have an included angle greater than 15 degrees. Two runways that diverge by more than 100 degrees are unlikely to be used together because of the effect of wind -- if there is a headwind on one runway, there would probably be a tailwind on the other.

There are three general categories of converging approaches, which are described below and depicted in Figure 2-1.

2.3.1 Intersecting Approach Streams

Converging approaches in which the final approaches intersect (Figure 2-1a) would be difficult to operate safely during any condition. There is little precedent for this operation during VFR conditions. Such geometries were not considered feasible for converging IFR operations and no examples are included in the survey.

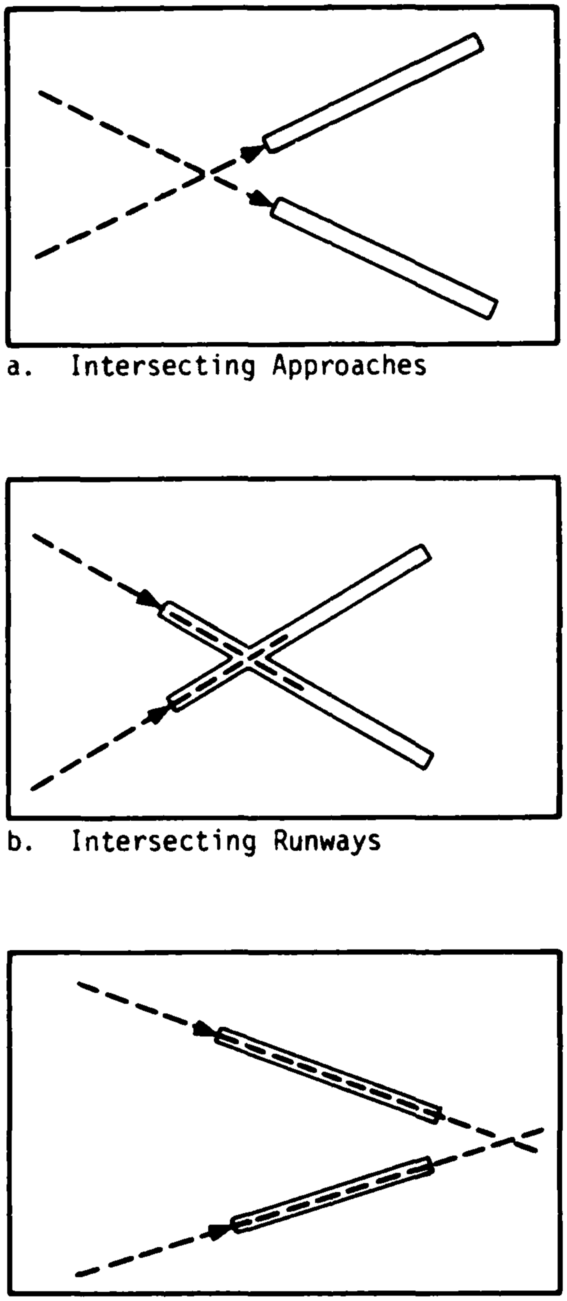
2.3.2 Intersecting Runways

Independent operations on converging runways that intersect (Figure 2-1b) pose two kinds of problems:

1. The possibility of collision between two aircraft on that portion of each runway in which the pavement is shared; and

2. The possibility of collision during simultaneous missed approaches.

Neither problem would necessarily prevent the independent operation of intersecting runways. The process of holding short before the intersection is practiced at several major airports (e.g., Chicago O'Hare) and can possibly be employed at other runway geometries with at least one long runway. The criteria for hold-short operations are found in Reference 11. The missed approach problem can also be resolved (see Reference 12). By requiring alternating, nonsimultaneous landings on the runways (called Dependent Converging Approaches), these two problems can be avoided with the penalty of smaller capacity gains then those achievable with independent operations.



a. Intersecting Approaches

b. Intersecting Runways

c. Converging Runway (Extended) Centerlines

FIGURE 2-1
TYPES OF CONVERGING APPROACHES

2.3.3 Converging Runway (Extended) Centerlines

Those runways in which the extended centerlines intersect, or a variation in which the extended centerline of one runway intersects the other runway, present only the problem of simultaneous missed approaches (Figure 2-1c). Because this category is the least complex, such an application of the converging concept is preferred.

2.3.4 Procedures for Converging Approaches

The primary study of converging approaches (Reference 10) proposed that adequate separation between missed approaches could be attained by application of the "worst-case boundary" criterion described in that study. That criterion has been applied to the candidate configurations to determine whether independent converging approaches are feasible.

Since the publication of that study, modified criteria for assuring separation have been proposed by the aviation industry and FAAs Air Traffic Service. These criteria, which are part of the FAA's current research and development activities, would allow wider application of the concept if they are accepted.

This study considers two categories of converging approaches:

1. Dependent approaches to intersecting runways, or to nonintersecting runways on which simultaneous landings are not permitted; and

2. Independent approaches to favorable nonintersecting runways, or to intersecting runways with "hold-short" procedures.

The selection criteria used in this survey of converging runways are:

1. Independent Converging Approaches - runways must be nonintersecting, or intersecting with one runway having at least 8400 feet from threshold to intersection, to allow hold-short operations by all aircraft (Table 2-1). Runways must meet preliminary requirements for IFR independent converging approaches (Reference 10).

2. Dependent Converging Approaches - intersecting or nonintersecting runways that could not meet the above requirements for independence. The available runway length on one runway must be at least 6000 feet, and 4000 feet on

TABLE 2-1
HOLD-SHORT CRITERIA FOR DEPENDENT
CONVERGING APPROACHES TO INTERSECTING RUNWAYS

DISTANCE TO HOLD SHORT (FT)	APPLICABLE AIRCRAFT
8400	All
8000	All except B-747
6000	B-727 and smaller
4500	Large twin propeller and smaller (except CV 580)
3000	STOL and small propeller aircraft (< 12,500 lbs.)
1650	STOL only

Source: Reference 7210.3G, Paragraph 1226.

the other. Available runway length is the distance from threshold to runway end, or threshold to intersection if hold-short procedures are required.

2.4 Independent and Dependent Triple Approaches

A logical combination of the first three concepts could result in the use of three runways simultaneously (Reference 12). Currently, no airport has three parallel runways, each 4300 feet apart; therefore, any triple configuration using existing pavement would include either one closely-spaced pair or one converging pair of runways. An example of a typical configuration is runways 19R/19L and 12, Figure 2-2, at Washington Dulles. This is very similar to the airport plan at Dallas/Ft. Worth. There is no present restriction on operating runways 19R and 19L independently, but because runway 12 converges, new procedures would be required to operate the three runways simultaneously under IFR. Triple arrival streams are currently used at Chicago O'Hare when weather conditions allow the use of visual separation techniques.

Three types of triple parallel approaches are considered (Figure 2-3):

1. Dependent/Dependent - the pair of approaches to the Center and Right runways are dependent, as are the approaches to the Center and Left runways. However, approaches to the Right and Left runways are independent of each other (this is true for all three types of triple approaches).

2. Independent/Dependent - approaches to the Center runway are independent of one runway, but dependent on the other.

3. Independent/Independent - approaches to the Center runway are independent of approaches on both the Right and the Left runways.

Triple runway configurations were selected only if one of the adjacent pairs of the triple met the conditions for independent parallel or independent converging operations.

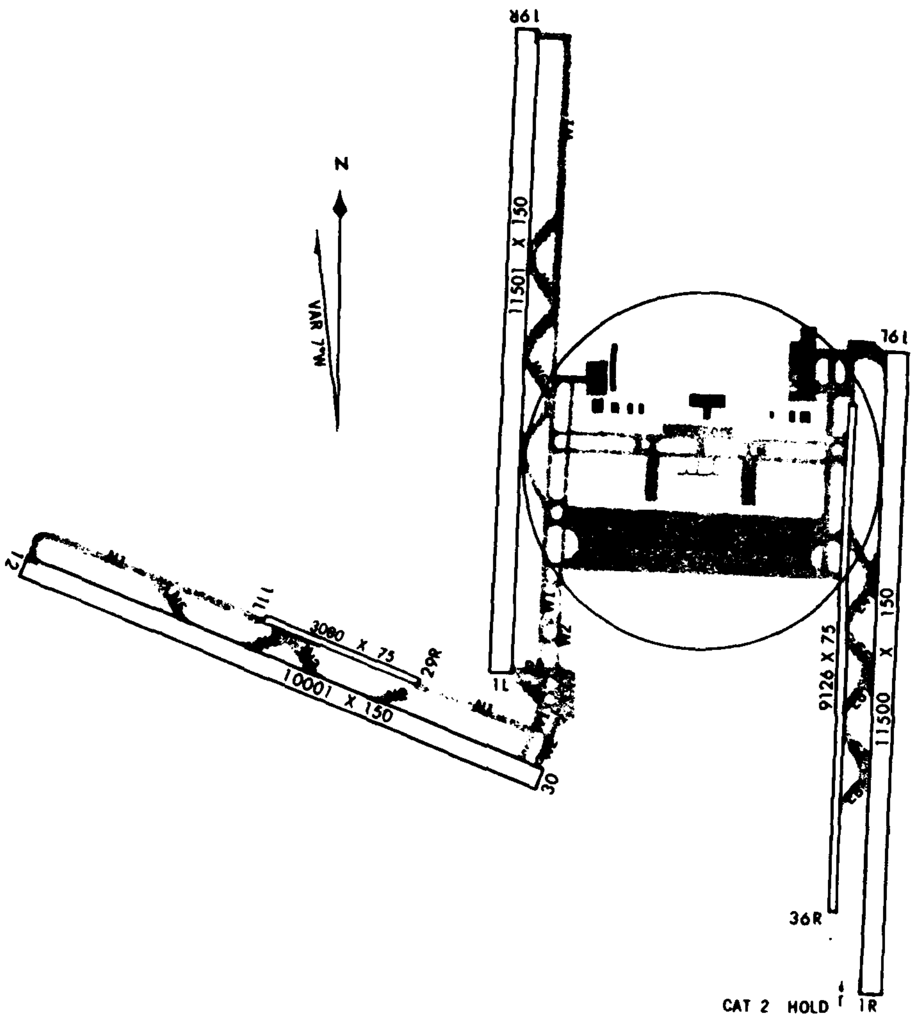


FIGURE 2-2
AIRPORT LAYOUT PLAN FOR WASHINGTON DULLES INTERNATIONAL

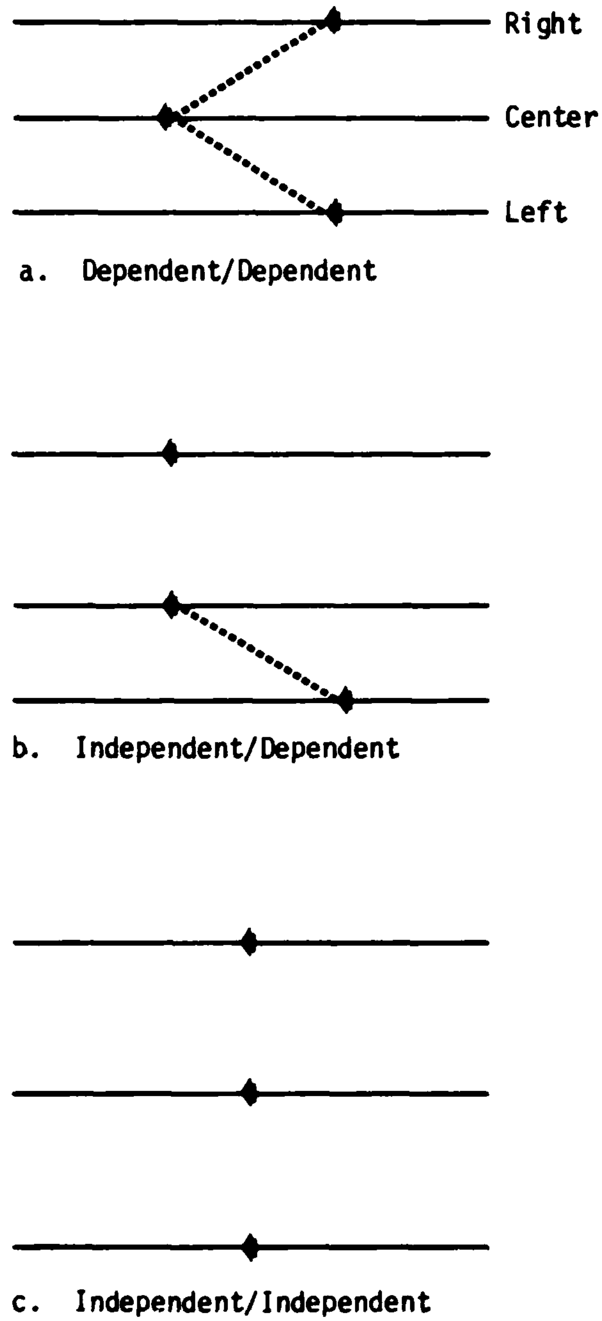


FIGURE 2-3
TYPES OF TRIPLE APPROACHES

2.5 Separate Short Runways

Currently, it is the convention to organize aircraft on approach according to time of arrival, not type of aircraft. This results in a string of unlike (i.e., slow/fast, heavy/light) aircraft, separated according to the rules as shown in Table 2-2. The object of segregating traffic streams is to minimize longitudinal distances between aircraft, thereby increasing throughput (Reference 13).

The concept of separate short runways involves the use of segregated traffic to relieve the demand on the main runway by using a short runway which would have a length of 4000 feet to 6000 feet and need not be built to accommodate the weight of large aircraft. The short runway could be a parallel, converging or a third runway to be used simultaneously with the main runway. If the short runway intersects with the main air carrier runway, then there must be sufficient distance from the threshold to the intersection to allow "land and hold-short" operations. (Figure 2-4.)

The selection criterion for including a separate short runway in this survey was only that its length be between 4000 feet and 6000 feet. As it turned out, all but three of the potential applications involve converging runways, most of which intersect with the main runway.

TABLE 2-2
IN-TRAIL SEPARATION (nmi)

LEAD AIRCRAFT	TRAIL AIRCRAFT		
	Small	Large	Heavy
Small	3*	3*	3*
Large	4	3*	3*
Heavy	6	5	4

Note: Small - defined as less than 12,500 pounds.
Large - between 12,500 and 300,000 pounds.
Heavy - over 300,000 pounds.
* A demonstration program is underway which may lead to a reduction in these distances from 3.0 nmi to 2.5 nmi.

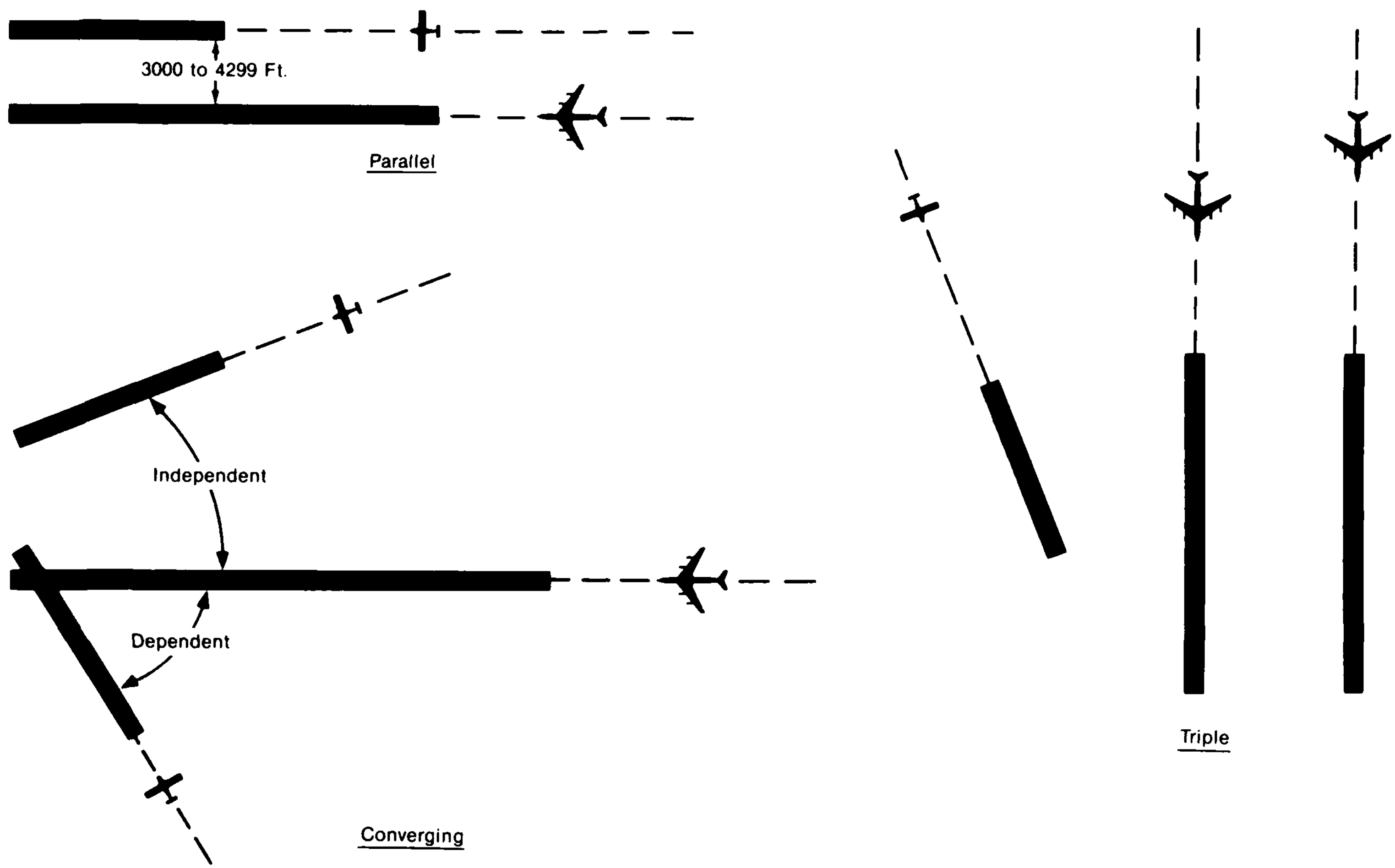


FIGURE 2-4
MULTIPLE APPROACH CONCEPTS
FOR SEPARATE SHORT RUNWAYS

3. APPLICATIONS

3.1 Airport Selection Criteria

The main purpose of this report is to determine potential site-specific applications of the concepts for multiple instrument approaches. 101 airports have been analyzed to determine such applicability. These airports were selected to include the busiest airports ranked by number of total aircraft operations excluding those airports with very little or no air carrier traffic.

Three airports (Denver Centennial (Arapahoe County), Spirit of St. Louis, and Seattle's Boeing Field), were included because they are among the 40 airports selected for capacity/delay task force studies. This list of 40 airports (Table 3-1) was proposed by the FAA offices of Airports (APP-400) and Air Traffic (ATO-400).

In addition to the "40 selected" airports mentioned above, the FAA has designated 22 airports as "pacing" airports (Table 3-2). The airports selected are those among the top 101 ranked by air carrier traffic including all the airports listed in the "40 selected" and the "22 pacing" airports.

3.2 Delays at 22 Pacing Airports

Table 3-3 shows the 1984 NASCOM delays at the 22 pacing airports. The NASCOM delays represent the number of aircraft reporting delays of more than 15 minutes at each airport. The total delay is in excess of 70,000 hours.

The delay figures reflect the levels of congestion at the busiest airports and highlight the need for improved airport capacity. The application of the concepts for multiple arrival streams during IFR weather will help increase airport capacity and hence reduce the excessively high number of delays seen today.

3.3 Survey of FAA Regions

The authors identified all the potential applications of each of the concepts at all 101 airports by performing a careful analysis of the airports layout plans. An original list of potential applications resulted from this analysis. A copy of this list and a corresponding questionnaire were sent to each of the Regional Offices under the coordination of the National Planning Division (APP-400) of the FAA's Office of Airport Planning and Programming. The questionnaire included questions

TABLE 3-1
AIRPORTS SELECTED FOR CAPACITY/DELAY TASK FORCE STUDY[1]

Atlanta (ATL)	Seattle (SEA)
New York (JFK)	Tampa (TPA)
Denver (DEN)	Phoenix (PHX)
New York (LGA)	New Orleans (MSY)
St. Louis (STL)	Cleveland (CLE)
Newark (EWR)	San Diego (SAN)
Baltimore (BWI)	Ft. Lauderdale (FLL)
Charlotte (CLT)	Kansas City (MCI)
San Francisco (SFO)	Dallas Love (DAL)
Los Angeles (LAX)	Memphis (MEM)
Dallas/Ft. Worth (DFW)	Portland (PDX)
Miami (MIA)	Salt Lake City (SLC)
Boston (BOS)	Buffalo (BUF)
Pittsburgh (PIT)	Cincinnati (CVG)
Houston (IAH)	San Antonio (SAT)
Detroit (DTW)	West Palm Beach (PBI)
Philadelphia (PHL)	Houston Hobby (HOU)
Minneapolis (MSP)	Seattle Boeing Field (BFI)
Honolulu (HNL)	Denver Centennial (APA)
Las Vegas (LAS)	Spirit of St. Louis (SUS)

1 List of airports proposed by FAA Offices of Airport Planning and Programming, National Planning Division (APP-400) and Air Traffic, Operations Division (AAT-400)

TABLE 3-2
LIST OF 22 PACING AIRPORTS

Chicago O'Hare International (ORD)

Atlanta Hartsfield International (ATL)

Los Angeles International (LAX)

Dallas - Fort Worth International (DFW)

Denver Stapleton International (DEN)

Miami International (MIA)

San Francisco International (SFO)

New York John F. Kennedy International (JFK)

New York La Guardia (LGA)

Washington National (DCA)

Boston Logan International (BOS)

St. Louis International (STL)

Pittsburgh International (PIT)

Detroit Metropolitan (DTW)

Houston Intercontinental (IAH)

Minneapolis St. Paul International (MSP)

Las Vegas McCarran (LAS)

Cleveland Hopkins International (CLE)

Philadelphia International (PHL)

Kansas City International (MCI)

Newark International (EWR)

Fort Lauderdale - Hollywood (FLL)

TABLE 3-3
DELAYS AT 22 PACING AIRPORTS

AIRPORT	1984 NASCOM DELAY[1]
Chicago (ORD)	25,316
Atlanta (ATL)	22,923
Los Angeles (LAX)	5,894
Dallas - Fort Worth (DFW)	10,785
Denver (DEN)	12,847
Miami (MIA)	7,654
San Francisco (SFO)	15,038
New York (JFK)	31,827
New York (LGA)	40,446
Washington (DCA)	11,593
Boston (BOS)	10,539
St. Louis (STL)	10,982
Pittsburgh (PIT)	6,074
Detroit (DTW)	6,107
Houston (IAH)	3,648
Minneapolis (MSP)	6,510
Las Vegas (LAS)	1,526
Cleveland (CLE)	3,692
Philadelphia (PHL)	6,713
Kansas City (MCI)	3,320
Newark (EWR)	26,841
Fort Lauderdale (FLL)	1,768
TOTAL	272,047

1 Number of aircraft reporting delays of more than 15 minutes.
Source: Federal Aviation Administration, National Aviation System Communications Staff (NASCOM) Office.

on the site-specific application of each of the concepts and covered areas such as technical feasibility, operational feasibility, airport master plan, other possibilities, etc. The questionnaire is shown in Appendix C.

The tables of potential applications presented in this report resulted from revising the original list to incorporate all of the information received from the FAA Regions. In some regions the response to the questionnaire was much more detailed and complete than in others. The site-specific information in this survey is based entirely on the responses to the questionnaire.

3.4 Description of Applications Tables

Tables 3-4 through 3-13 and Appendix A list all of the potential applications for each of the multiple approach concepts at 101 U.S. airports. Listed under each concept are the pairs of runways (three in the case of triple approaches) to which simultaneous approaches are to be executed. In the case of dependent and independent parallel approaches the spacing between runways is provided (e.g., 4R,4L (3000') means a separation of 3000 feet exists between runways 4R and 4L). In the case of separate short runways, the runway listed in second place is the one to be used as a short runway (e.g., 29,27R means runway 27R is the short runway and runway 29 is the main carrier runway). In all cases, the applications listed involve the use of existing concrete.

3.4.1 Summary of Concept Application to 101 Airports

Table 3-4 lists all of the airports in rank order according to total number of aircraft operations (except for the last three which were included for the reasons discussed in section 3.1). They are numbered 1 through 101. All potential applications at each airport have been included.

3.4.2 Summary of Concept Application to 101 Airports by FAA Region

Tables 3-5 through 3-13 contain the same information as Table 3-4 but show the airports grouped by FAA Region. The nine FAA Regions in alphabetical order and the states that each one includes are the following: (Puerto Rico is included in the Southern Region.)

Alaskan Region: Alaska

Central Region: Iowa, Kansas, Missouri, Nebraska

TABLE 3-4
SUMMARY OF CONCEPT APPLICATION TO 101 AIRPORTS

	AIRPORTS	DEPENDENT PARALLELS	INDEPENDENT PARALLELS	DEPENDENT CONVERGING	INDEPENDENT CONVERGING	TRIPLES	SEPARATE SHORT RUNWAYS
1.	Chicago (ORD)				22R,27L 32L,27R 9L,4R 9R,4R 9R,14L	9L,9R,4R 27L,27R,22R 22L,22R,14R	
2.	Atlanta (ATL)	8L,8R (1000') 9L,9R (1000')				8,9R,9L	
3.	Los Angeles (LAX)						
4.	Denver (DEN)	17R,17L (1600')			17L,26L		
5.	Dallas Ft. Worth (DFW)				35L/R,31R 36L/R,31R	36L/R,35L/R,31R	
6.	Oakland (OAK)	27L,27R (1000')			29,27L 29,27R		29,27R
7.	San Francisco (SFO)			10L,1R 28R,1R			10L,1R 28R,1R
8.	St. Louis (STL)	30R,30L (1300')		24,30L	24,30R		24,30L
9.	New York (JFK)		4R,4L (3000')	13L,4L	13R,22L 13L,4R		
10.	Phoenix (PHX)		8R,8L (3400') 26R,26L (3400')				
11.	Miami (MIA)			12,9R	27R,30		
12.	New York (LGA)			4,31 13,4			4,31 13,4
13.	Boston (BOS)	22R,22L (1500')		4R,33L			4R,33L 14-32*
14.	Houston (IAH)				26,32R		
15.	Washington (DCA)			36,33			
16.	Honolulu (HNL)			8L,4R			8L,4R
17.	Philadelphia (PHL)	9L,9R (1400')		9L,17	17,9R		9L,17 10-28*

TABLE 3-4
(Continued)

	AIRPORTS	DEPENDENT PARALLELS	INDEPENDENT PARALLELS	DEPENDENT CONVERGING	INDEPENDENT CONVERGING	TRIPLES	SEPARATE SHORT RUNWAYS
18.	San Jose (SJC)						
19.	Pittsburgh (PIT)	10R,10C (1200')		14,10C 14,10R		10L,10C,10R	10R,14
20.	Houston Hobby (HOU)			17,22 22,31L			17,22 22,31L
21.	Dallas Love (DAL)	31L,31R (2975') 13R,13L (2975')					
22.	Minneapolis (MSP)		11R,11L (3380') 29R,29L (3380')	22,29L			29L,22
23.	Las Vegas (LAS)			19R,25			25,19R
24.	Memphis (MEM)		36L,36R (3400') 18L,18R (3400')	21,27	36L,27 36R,27 36R,3 21,18R		21,27
25.	Charlotte, NC (CLT)			5,36R	18R,23		5,36R
26.	Salt Lake City (SLC)		16L,16R (3500')		14,16L 34L,32		14,16L 34L,32
27.	Tampa (TPA)			27,18L	27,18R		27,18L
28.	Detroit (DTW)	3C,3R (2000')	3L,3C (3800')		3R,9 21R,27	3R,3C,3L	
29.	Newark (EWR)			11,4R	11,4L		
30.	Baltimore (BWI)			15R,10 15R,22 33L,28			15R,10 15R,22 33L,28

TABLE 3-4
(Continued)

	AIRPORTS	DEPENDENT PARALLELS	INDEPENDENT PARALLELS	DEPENDENT CONVERGING	PENDENT RGING	TRIPLES	SEPARATE SHORT RUNWAYS
31.	Fort Lauderdale (FLL)		[illegible] (4000') [illegible] (4000')	27R,31			[illegible],27R [illegible],9R [illegible]7R,3[illegible]
32.	Tucson (TUS)						
33.	Columbus (CMH)	10L,10R (2800')			31,28R 5,10L		28R,3[illegible]
34.	West Palm Beach (PBI)			13,9L			[illegible],13
35.	Tulsa (TUL)			17R,26			17R,26
36.	Anchorage (ANC)				14,6R		
37.	Chicago Midway (MDW)						
38.	Albuquerque (ABQ)						
39.	San Antonio (SAT)			12R,21			12R,21
40.	Cleveland (CLE)			10L,5R 10L,5L			10L,5L 5R,10L
41.	Seattle (SEA)						
42.	Portland (PDX)		28L,28R (3100')	10R,2 28L,2			2,28L
43.	Birmingham (BHM)						
44.	Nashville, TN (BNA)	2L,2R (1800')		2L,31			31,2L 31,2R
45.	Daytona Beach (DAB)			16,6L			16,6L
46.	Fresno (FAT)						

TABLE 3-4
(Continued)

AIRPORTS	DEPENDENT PARALLELS	INDEPENDENT PARALLELS	DEPENDENT CONVERGING	INDEPENDENT CONVERGING	TRIPLES	SEPARATE SHORT RUNWAYS
47. Providence (PVD)	5L,5R (1700')		34,5R			34,5R
			28,34			28,34
48. Austin, TX (AUS)			35L,31L			31L,35L
49. Burbank (BUR)			7,15			7,15
50. El Paso, TX (ELP)	26L,26R (1200')			22,26R		22,26L
						22,26R
51. Grand Forks, ND (GFK)			26,35			26,35
52. Raleigh (RDU)			32,5			32,5
53. St. Petersburg (PIE)			22,17L			22,17L
			4,9			4,9
54. Indianapolis (IND)			4L,31			4L,31
			13,4L			13,4L
55. New Orleans (MSY)				10,19		
56. San Juan, PR (SJU)				25,28		
57. Wichita (ICT)				14,19L		
58. Norfolk (ORF)			23,14			14,23
						32,23
59. Sarasota (SRQ)----------	----------	----------	----------	----------	----------	----------
60. Des Moines (DSM)			12L,5			5,12L
61. Milwaukee (MKE)	1L,1R (1000')		7R,1L	13,7R		13,7R
62. Cincinnati (CVG)	27R,27L (1700')		27L,36			36,27L
			18,27L			18,27L

TABLE 3-4
(Continued)

	AIRPORTS	DEPENDENT PARALLELS	INDEPENDENT PARALLELS	DEPENDENT CONVERGING	INDEPENDENT CONVERGING	TRIPLES	SEPARATE SHORT RUNWAYS
63.	Buffalo (BUF)			14,5			14,5
64.	Oklahoma City (OKC)				12,17L		
65.	Orlando (MCO)	18L,18R (1600')					
66.	Washington Dulles (IAD)				12,19L	12,19R,19L	
					12,19R		
67.	Baton Rouge (BTR)—						
68.	Little Rock (LIT)				18,22		18,22
69.	Richmond Byrd Intl. (RIC)				2,33		15,6
					20,24		33,6
70.	Boise (BOI)—						
71.	Madison, WI (MSN)			36,31	18,22		36,31
							18,22
72.	Kansas City (MCI)				19,27		
73.	Albany (ALB)			28,1			28,1
74.	Reno (RNO)			16,25			25,16
							7,16
75.	Dayton (DAY)			18,24L	6L,36		18,24L
76.	Omaha (OMA)	32L,32R		17,14R			17,14R
		14R,14L					32L,32R
							14R,14L
77.	Syracuse (SYR)			14,10			10,14
78.	Louisville, KY (SDF)			29,24			29,24
							6,1
79.	Windsor Locks (BDL)						24,33
							6,1
80.	San Diego (SAN)—						

TABLE 3-4
(Concluded)

	AIRPORTS	DEPENDENT PARALLELS	INDEPENDENT PARALLELS	DEPENDENT CONVERGING	INDEPENDENT CONVERGING	TRIPLES	SEPARATE SHORT RUNWAYS
81.	Fairbanks (FAI)						
82.	Jacksonville (JAX)				31,25		
83.	Greensboro, NC (GSO)			23,14			14,23
							32,23
84.	Manchester, NH (MHT)			35,6			35,6
85.	Charleston, SC (CHS)			33,3			33,3
86.	Corpus Christi (CRP)				13,17		13,17
87.	Rockford, IL (RFD)			36,6			36,6
				18,12			18,12
88.	Grand Rapids, MI (GRR)						
89.	Billings, MT (BIL)			34,27R	16,22		16,22
							34,27R
90.	Burlington (BTV)						
91.	Knoxville, TN (TYS)	5L,5R (1200')					5L,5R
92.	Lansing (LAN)						
93.	Kahului, Hawaii (HOG)			5,2			5,2
94.	Lubbock TX (LBB)						17R,26
							35L,26
95.	Niagara Falls, NY (IAG)			28R,32			28R,32
				10L,6			10L,6
96.	Sacramento (SMF)						
97.	Ontario (ONT)			21,26L			21,26L
				21,26R			21,26R
98.	Akron Canton, OH (CAK)						14,19
99.	Boeing Field (BFI)						
100.	Centennial, CO (APA)						
101.	Spirit of St. Louis (SUS)						

TABLE 3-5
SUMMARY OF CONCEPT APPLICATION TO 101 AIRPORTS
ALASKAN REGION

AIRPORTS	DEPENDENT PARALLELS	INDEPENDENT PARALLELS	DEPENDENT CONVERGING	INDEPENDENT CONVERGING	TRIPLES	SEPARATE SHORT RUNWAYS
1. Anchorage (ANC)				14,6R		
2. Fairbanks (FAI)	----	----	----	----	----	----

TABLE 3-6
SUMMARY OF CONCEPT APPLICATION TO 101 AIRPORTS
CENTRAL REGION

AIRPORTS	DEPENDENT PARALLELS	INDEPENDENT PARALLELS	DEPENDENT CONVERGING	INDEPENDENT CONVERGING	TRIPLES	SEPARATE SHORT RUNWAYS
1. St. Louis (STL)	30R,30L (1300')		24,30L	24,30R		24,30L
2. Wichita (ICT)				14,19L		
3. Des Moines (DSM)			12L,5			5,12L
4. Kansas City (MCI)				19,27		
5. Omaha (OMA)	32L,32R 14R,14L		17,14R			17,14R 32L,32R 14R,14L
6. Spirit of St. Louis (SUS)----------	----------	----------	----------	----------	----------	----------

TABLE 3-7
SUMMARY OF CONCEPT APPLICATION TO 101 AIRPORTS
EASTERN REGION

AIRPORTS	DEPENDENT PARALLELS	INDEPENDENT PARALLELS	DEPENDENT CONVERGING	INDEPENDENT CONVERGING	TRIPLES	SEPARATE SHORT RUNWAYS
1. New York (JFK)		4R,4L (3000')	13L,4L	13R,22L 13L,4R		
2. New York (LGA)			4,31			4,31
3. Washington (DCA)			36,33			
4. Philadelphia (PHL)	9L,9R (1400')		17,9L	17,9R		9L,17
5. Pittsburgh (PIT)	10R,10C (1200')		14,10C 14,10R		10L,10C,10R	10R,14
6. Newark (EWR)			11,4R	11,4L		
7. Baltimore (BWI)			15R,10 15R,22 33L,28			15R,10 15R,22 33L,28
8. Norfolk (ORF)			23,14 32,23			14,23 32,23
9. Buffalo (BUF)			14,5			14,5
10. Washington Dulles (IAD)				12,19L 12,19R	12,19R,19L	
11. Richmond Byrd Intl. (RIC)			15,6 33,6	2,33 20,24		15,6 33,6
12. Albany (ALB)			28,1			28,1
13. Syracuse (SYR)			14,10			10,14
14. Niagara Falls, NY (IAG)			28R,32 10L,6			28R,32 10L,6

TABLE 3-8

SUMMARY OF CONCEPT APPLICATION TO 101 AIRPORTS

GREAT LAKES REGION

AIRPORTS	DEPENDENT PARALLELS	INDEPENDENT PARALLELS	DEPENDENT CONVERGING	INDEPENDENT CONVERGING	TRIPLES	SEPARATE SHORT RUNWAYS
1. Chicago (ORD)				22R,27L 32L,27R 9L,4R 9R,4R 9R,14L	9L,9R,4R 27L,27R,22R 22L,22R,14R	
2. Minneapolis (MSP)		11R,11L (3380') 29R,29L (3380')	22,29L			29L,22
3. Detroit (DTW)	3C,3R (2000')	3L,3C (3800')		3R,9 21R,27	3R,3C,3L	
4. Columbus (CMH)	10L,10R (2800')			31,28R 5,10L		28R,31
5. Chicago Midway (MDW)						
6. Cleveland (CLE)			10L,5R 10L,5L			10L,5L 5R,10L
7. Grand Forks, ND (GFK)			26,35			26,35
8. Indianapolis (IND)			4L,31 13,4L			4L,31 13,4L
9. Milwaukee (MKE)	1L,1R (1000')		7R,1L	13,7R		13,7R
10. Madison, WI (MSN)			36,31	18,22		36,31 18,22
11. Dayton (DAY)			18,24L	6L,36		18,24L
12. Rockford, IL (RFD)			36,6 18,12			36,6 18,12
13. Grand Rapids, MI (GRR)						
14. Lansing (LAN)						
15. Akron Canton, OH (CAK)			14,19			14,19

TABLE 3-9
SUMMARY OF CONCEPT APPLICATION TO 101 AIRPORTS
NEW ENGLAND REGION

AIRPORTS	DEPENDENT PARALLELS	INDEPENDENT PARALLELS	DEPENDENT CONVERGING	INDEPENDENT CONVERGING	TRIPLES	SEPARATE SHORT RUNWAYS
1. Boston (BOS)	22R,22L (1500')		4R,33L			4R,33L
2. Providence (PVD)	5L,5R (1700')		34,5R 28,34			34,5R 28,34
3. Windsor Locks (BDL)			24,33 6,1			24,33 6,1
4. Manchester, NH (MHT)			35,6			35,6
5. Burlington (BTV)-------	-------	-------	-------	-------	-------	-------

TABLE 3-10
SUMMARY OF CONCEPT APPLICATION TO 101 AIRPORTS
NORTHWEST MOUNTAIN REGION

AIRPORTS	DEPENDENT PARALLELS	INDEPENDENT PARALLELS	DEPENDENT CONVERGING	INDEPENDENT CONVERGING	TRIPLES	SEPARATE SHORT RUNWAYS
1. Denver (DEN)	17R,17L (1600')			17L,26L		
2. Salt Lake City (SLC)		16L,16R (3500')		14,16L 34L,32		14,16L 34L,32
3. Seattle (SEA)						
4. Portland (PDX)		28L,28R (3100')	10R,2 28L,2			2,28L
5. Boise (BOI)						
6. Billings, MT (BIL)			34,27R	16,22		16,22 34,27R
7. Boeing Field (BFI)						
8. Centennial, CO (APA)						

TABLE 3-11
SUMMARY OF CONCEPT APPLICATION TO 101 AIRPORTS
SOUTHERN REGION

AIRPORTS	DEPENDENT PARALLELS	INDEPENDENT PARALLELS	DEPENDENT CONVERGING	INDEPENDENT CONVERGING	TRIPLES	SEPARATE SHORT RUNWAYS
1. Atlanta (ATL)	8L,8R (1000')				8,9R,9L	
	9L,9R (1000')					
2. Miami (MIA)			12,9R	27R,30		
3. Memphis (MEM)		36L,36R (3400')	21,27	36L,27		21,27
		18L,18R (3400')		36R,27		
				36R,3		
				21,18R		
4. Charlotte, NC (CLT)			5,36R	18R,23		5,36R
5. Tampa (TPA)			27,18L	27,18R		27,18L
6. Fort Lauderdale (FLL)		27L,27R (4000')	27R,31			27L,27R
		9L,9R (4000')				9L,9R
						27R,31
7. West Palm Beach (PBI)			13,9L			9L,13
8. Birmingham (BHM)						
9. Nashville, TN (BNA)	2L,2R (1800')		2L,31	31,2R		31,2L
						31,2R
10. Daytona Beach (DAB)			16,6L			16,6L
11. Raleigh (RDU)			32,5			32,5
12. St. Petersburg (PIE)			22,17L			22,17L
			4,9			4,9
13. San Juan, PR (SJU)				25,28		
14. Sarasota (SRQ)						
15. Cincinnati (CVG)	27R,27L (1700')		27L,36			36,27L
			18,27L			18,27L
						27R,27L
16. Orlando (MCO)	18L,18R (1600')					
17. Louisville, KY (SDF)			29,24			29,24
			6,1			6,1
18. Jacksonville (JAX)				31,25		
19. Greensboro, NC (GSO)			23,14			14,23
			32,23			32,23
20. Charleston, SC (CHS)			33,3			33,3
21. Knoxville, TN (TYS)	5L,5R (1200')					5L,5R

TABLE 3-12
SUMMARY OF CONCEPT APPLICATION TO 101 AIRPORTS
SOUTHWEST REGION

AIRPORTS	DEPENDENT PARALLELS	INDEPENDENT PARALLELS	DEPENDENT CONVERGING	INDEPENDENT CONVERGING	TRIPLES	SEPARATE SHORT RUNWAYS
1. Dallas Ft. Worth (DFW)				35L/R,31R 36L/R,31R	36L/R,35L/R,31R	
2. Houston (IAH)				26,32R		
3. Houston Hobby (HOU)			17,22 22,31L			17,22 22,31L
4. Dallas Love (DAL)	31L,31R (2975') 13R,13L (2975')					
5. Tulsa (TUL)			17R,26			17R,26
6. Albuquerque (ABQ)						
7. San Antonio (SAT)			12R,21			12R,21
8. Austin, TX (AUS)			35L,31L			31L,35L
9. El Paso, TX (ELP)	26L,26R (1200')			22,26R 22,26L		22,26L 22,26R
10. New Orleans (MSY)				10,19		
11. Oklahoma City (OKC)				12,17L		
12. Baton Rouge (BTR)						
13. Little Rock (LIT)				18,22		18,22
14. Corpus Christi (CRP)				13,17		13,17
15. Lubbock TX (LBB)			17R,26 35L,26			17R,26 35L,26

TABLE 3-13
SUMMARY OF CONCEPT APPLICATION TO 101 AIRPORTS
WESTERN PACIFIC REGION

AIRPORTS	DEPENDENT PARALLELS	INDEPENDENT PARALLELS	DEPENDENT CONVERGING	INDEPENDENT CONVERGING	TRIPLES	SEPARATE SHORT RUNWAYS
1. Los Angeles (LAX)	------	------	------	------	------	------
2. Oakland (OAK)	27L,27R (1000')			29,27L 29,27R		29,27R
3. San Francisco (SFO)			10L,1R 28R,1R			10L,1R 28R,1R
4. Phoenix (PHX)		8R,8L (3400') 26R,26L (3400')				
5. Honolulu, (HNL)			8L,4R			8L,4R
6. San Jose (SJC)	------	------	------	------	------	------
7. Las Vegas (LAS)			19R,25			19R,25
8. Tucson (TUS)	------	------	------	------	------	------
9. Fresno (FAT)	------	------	------	------	------	------
10. Burbank (BUR)			7,15			7,15
11. Reno (RNO)			16,25 7,16			25,16 7,16
12. San Diego (SAN)	------	------	------	------	------	------
13. Kahului, Hawaii (HOG)			5,2			5,2
14. Sacramento (SMF)	------	------	------	------	------	------
15. Ontario (ONT)			21,26L			21,26L

Eastern Region: Delaware, Maryland, New Jersey, New York, Pennsylvania, Virginia, West Virginia

Great Lakes Region: Illinois, Indiana, Michigan, Minnesota, North Dakota, Ohio, South Dakota, Wisconsin

New England Region: Conneticut, Massachusetts, Maine, New Hampshire, Rhode Island, Vermont

Northwest Mountain Region: Colorado, Idaho, Montana, Oregon, Utah, Washington, Wyoming

Southern Region: Alabama, Florida, Georgia, Kentucky, Mississippi, North Carolina, Puerto Rico, South Carolina, Tennesee

Southwest Region: Arkansas, Louisiana, New Mexico, Oklahoma, Texas

Western Pacific Region: Arizona, California, Hawaii, Nevada

Within each Region, airports are listed in rank order according to total number of aircraft operations.

Appendix A also presents the airports clustered by FAA Region. In addition to the complete list of applications at each airport, this appendix provides a figure with the airport layout and some remarks for each of the 101 airports.

4. EVALUATION OF DELAY SAVINGS FOR A REPRESENTATIVE GROUP OF AIRPORTS

This section presents a few examples of the benefits (in terms of delay savings) that can be achieved with the implementation of the multiple IFR arrival stream concepts. The examples presented represent each of the potential applications identified in section 3. The delay savings are expressed in hours per day and refer to the amount of hours of delay saved during IFR conditions by shifting from the current airport configuration to one of the multiple approach procedures.

4.1 Methodology

The methodology used to calculate the delay savings is similar to the one used in the earlier study of 101 U.S. airports (Reference 7). The reductions in delays are a function of improvement in capacity as a result of concept implementation, the level and pattern of demand at each airport, and the percentage of IFR conditions.

The steps followed to calculate delays were:

1. The capacity of each airport was calculated (using the FAA Airfield Capacity Model, reference 14) for the applicable concepts analyzed.

2. A daily demand profile (the number of arrivals in each of the 24 hours) was constructed for each airport based on the number of scheduled and general aviation operations.

3. The capacity values and the demand profiles were used as an input to an analytical model that calculated the total daily delay.

Each of these steps is described below.

The delay savings presented in this section correspond to arrival delays. Nevertheless, the arrival capacity of each airport was calculated taking into consideration departures. It was assumed that at least 50 percent of all operations were departures. Although this differs from the way in which capacity was calculated in the earlier study of 101 airports (Reference 7), it should be noted that there were no major changes in the arrival capacities. This is because during IFR conditions the separations between arriving aircraft are such that, on the average, it is possible to insert a departure between each pair of arrivals without diminishing the arrival capacity.

4.1.1 Capacity Calculations

Capacity was calculated using the Upgraded FAA Airfield Capacity Model (Reference 14). This model computes the maximum throughput of the given runway configuration by first calculating an average time between successive arrivals, then inverting this value to give the number of arrivals per hour. As mentioned in the previous section, it was assumed that there was an equal number of arrivals and departures.

The arrival capacity for some of the new concepts could not be obtained directly from the FAA Capacity Model. These capacities were calculated as follows:

1. Independent Converging Approaches: equal to the capacity of two independent approaches.

2. Dependent Converging Approaches: calculated by the method outlined in Appendix E of Reference 10. This capacity is dependent upon the geometry of the runway layout, particularly the threshold locations.

3. Independent/Independent Triple Approaches: equal to three times the capacity of a single runway.

Appendix D contains the input values used to calculate capacity. These values reflect current-day performance of aircraft and the air traffic control system.

The aircraft fleet mix at each airport used as input to the capacity calculations was assumed to be the same used in Reference 7. The fleet mix has less of an effect on airport capacity than, for example, the type of instrument approaches in use. Thus, if the assumed fleet mix is not entirely accurate it will have little effect on the final result.

4.1.2 Demand Calculations

The daily demand profiles constructed correspond to a Friday in August 1985. They are based on the Official Airline Guide (OAG) data for August 1985. The OAG data includes all scheduled operations at each airport (air carrier, air transport and commuters), and can be broken down by hour of the day. The hourly figures obtained from the OAG data were then adjusted to account for the general aviation traffic at each airport. Daily amounts of general aviation traffic were obtained from Airport Traffic Records (FAA Form 7230-1). The hourly demand at each airport is shown in Appendix D.

Air Traffic for a Friday in August is usually one the highest daily traffics throughout the year. Therefore the hourly demand used in this case corresponds to a peak demand during 1985 at each of the airports studied. Given the steady growth in air traffic, this peak demand will become an average-day demand in the near future; probably at the time when the concepts will be widely implemented.

4.1.3 Delay Calculations

Given the hourly demand profile and the arrival capacity, it was possible to calculate the expected delay. A version of the MIT "DELAYS" model (Reference 15) was used to calculate the delay at the airports analyzed. This analytical model solves a number of time-dependent queueing equations to compute the average delay per aircraft during each hour. This average delay was then multiplied by the hourly demand and summed over the 24 hours to provide a total daily delay (over all aircraft).

This resulting total delay represents 24 hours of continuous IFR operations on the given runway configuration. To reflect the occurrence of actual IFR conditions these totals were multiplied by the percentage of IFR conditions to derive an expected daily IFR delay. Reference 16 was used to obtain the annual percentage of IFR weather, between 1500 feet ceiling and 3 miles and 200 feet/0.5 miles (CAT I minima).

4.2 Results

The following are examples of the benefits in terms of delay savings that can be achieved during IFR with each of the multiple arrival stream concepts. These delay savings were calculated using the methodology described in the previous section. In order to evaluate the benefits in terms of dollars it would be necessary to multiply the amount of hours of delay saved times a dollars-per-hour-of-delay factor. As mentioned before, delay savings depend on capacity and the volume and pattern of the daily demand.

4.2.1 Dependent Parallel Approaches

Two airports have been studied for delay savings resulting from the application of dependent parallel approaches at reduced runway centerline spacing. These airports are Boston Logan (BOS) and Philadelphia International (PHL). Table 4-1 shows the results obtained. The "delay savings" result from subtracting the delay for the dependent parallel configuration from the delay for the "best previous" configuration.

TABLE 4-1
DELAY SAVINGS WITH DEPENDENT PARALLEL APPROACHES

		Configuration					
		Best Previous			Dependent Parallel		
Airport	% IFR	Type	Capacity[1]	Delay[2]	Capacity[1]	Delay[2]	Delay Savings[2]
BOS	15	Single runway	25.6	346	37.0	87	259
PHL	15	Single runway	25.2	51	35.7	7	44

1 - Arrivals/hour
2 - Hours/day

4.2.2 Independent Parallel Approaches

Memphis International Airport (MEM) and New York's John F. Kennedy Airport (JFK) have been studied to determine the delay savings achievable with independent parallel approaches at reduced runway centerline spacings. Table 4-2 contains the results. This table shows two sets of capacities and delay savings for each airport. One illustrates the improvements achievable over a single runway configuration and the other those achievable over a dependent parallel configuration. At both of these airports, MEM and JFK, dependent parallel operations are allowed under today's rules although they are not necessarily being used.

4.2.3 Dependent Converging Approaches

John F. Kennedy and Newark International (EWR) airports were selected for determining the delay savings achievable with dependent converging approaches. Results are shown in Table 4-3.

4.2.4 Independent Converging Approaches

Table 4-4 shows the capacity improvements and delay savings achievable with independent converging approaches. Houston Intercontinental (IAH) and Newark nternational airports were studied in this case.

4.2.5 Triple Approaches

Dallas-Fort Worth International Airport (DFW) was analyzed to determine the delay savings achievable with the implementation of triple approaches. The results are shown in Table 4-5. In the case of DFW the triple approaches correspond to two parallel and one converging runways. All three approaches would be independent from each other.

4.3 Summary

A representative sample of the different applications of the concepts was chosen for the purpose of estimating the benefits of implemention.

It was found that arrival delays were significantly reduced in each case as shown in Table 4-6. These savings are for arriving aircraft and assume that an equal number of aircraft will depart.

TABLE 4-2
DELAY SAVINGS WITH INDEPENDENT PARALLEL APPROACHES

		Configuration					
		Best Previous			Independent Parallel		
Airport	% IFR	Type	Capacity[1]	Delay[2]	Capacity[1]	Delay[2]	Delay Savings[2]
MEM	9	Single runway	24.6	27	49.2	3	24
		Dep. parallel	35.1	9	49.2	3	6
JFK	14	Single runway	24.5	157	49.0	15	142
		Dep. parallel	36.8	52	49.0	15	37

1 - Arrivals/hour
2 - Hours/day

TABLE 4-3
DELAY SAVINGS WITH DEPENDENT CONVERGING APPROACHES

		Configuration					
		Best Previous			Dependent Parallel		
Airport	% IFR	Type	Capacity[1]	Delay[2]	Capacity[1]	Delay[2]	Delay Savings[2]
JFK	14	Single runway	24.5	157	43.4	26	131
		Dep. parallel	36.8	52	43.4	26	26
EWR	16	Single runway	25.3	216	43.8	7	209

1 - Arrivals/hour
2 - Hours/day

TABLE 4-4
DELAY SAVINGS WITH INDEPENDENT CONVERGING APPROACHES

		Configuration					
		Best Previous			Independent Converging		
Airport	% IFR	Type	Capacity[1]	Delay[2]	Capacity[1]	Delay[2]	Delay Savings[2]
IAH	15	Single runway	25.4	124	50.8	3	121
EWR	16	Single runway	25.3	216	50.6	4	212

1 - Arrivals/hour
2 - Hours/day

TABLE 4-5
DELAY SAVINGS WITH TRIPLE APPROACHES

		Configuration					
		Best Previous			Triples		
Airport	% IFR	Type	Capacity[1]	Delay[2]	Capacity[1]	Delay[2]	Delay Savings[2]
DFW	8	Single runway	26.5	261	79.5	2	259
		Indep. parallel	53.0	18	79.5	2	16

1 - Arrivals/hour
2 - Hours/day

TABLE 4-6
SUMMARY OF DELAY SAVINGS[1]

Airport	Concept to be used	Estimated Delay Savings (Hrs/Day)
Boston (BOS)	Dependent Parallels	259
Philadephia (PHL)	Dependent Parallels	44
Memphis (MEM)	Independent Parallels	6[2]
New York (JFK)	Independent Parallels	37[2]
New York (JFK)	Dependent Converging	26[2]
Newark (EWR)	Dependent Converging	209
Houston (IAH)	Independent Converging	121
Newark (EWR)	Independent Converging	212
Dallas-Fort Worth (DFW)	Triple Approaches	16[3]

1 - Arrival delays (assuming at least 50% of all operations are departures).

2 - Assumes Dependent Parallels as current configuration. Delay savings over single runway configuration are substantially larger.

3 - Assumes Independent Parallels as current configuration. Delay savings over single runway configuration are substantially larger.

5. CONCLUSIONS

At a number of airports, issues such as the lack of landing aids and airspace restrictions must be resolved as a prerequisite for concept application.

20 airports showed no potential for application of any of the concepts.

Of the 101 airports studied in this report, the following number of airports were found to be potential candidates for the application of each concept using existing runways:

1. Parallel approaches at reduced runway spacing: 25 airports. Note that some airports have both dependent and independent parallel applications.

    a. dependent parallel approaches: 18 airports.
    b. independent parallel approaches: 8 airports.

2. Converging approaches: 74 airports. Note that some airports have both dependent and independent converging applications.

    a. dependent converging approaches: 52 airports.
    b. independent converging approaches: 32 airports.

3. Triple approaches: 6 airports.

4. Separate short runway: 60 airports.

This survey restricted itself to potential applications of the concepts to existing runways. Once the concepts are accepted, there may be many airports which can increase their capacity by building new runways or lengthening existing runways to utilize these new multiple instrument approach procedures.

APPENDIX A
CONCEPT APPLICATION TO 101 AIRPORTS

Tables A-1 through A-9 shown in this appendix present the airports clustered by FAA Region as in Tables 3-5 through 3-13. In addition to the complete list of applications at each airport, Tables A-1 through A-9 provide a figure with the airport layout and some remarks for each of the 101 airports. The figures showing the airport geometry should allow the reader to visualize more easily each of the listed applications.

The "Remarks" contain issues that must be addressed when considering the applications listed in the tables. These remarks are based entirely on information provided by the responses to the questionnaire that was sent to each FAA Region.

An alphabetical index of airports is provided in Appendix B to aid the reader in finding specific airports.

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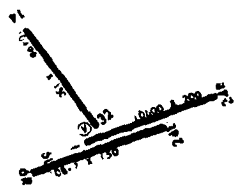
TABLE A-1
ALASKAN REGION

TABLE A-1
(Concluded)

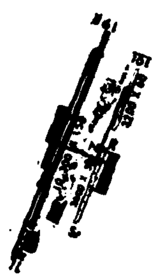
ANCHORAGE (ANC)



Dependent Parallels	Independent Parallels	Dependent Converging	Independent Converging	Triples	Separate Short Runway
			14,6R		

Remarks: - Runway 14 does not have ILS.
- Airspace restrictions due to GA aircraft.

FAIRBANKS (FAI)



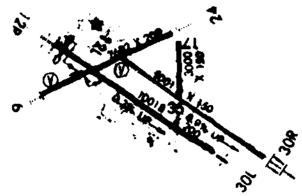
Dependent Parallels	Independent Parallels	Dependent Converging	Independent Converging	Triples	Separate Short Runway

Remarks: - No applications.

TABLE A-2
CENTRAL REGION

TABLE A-2
(Continued)

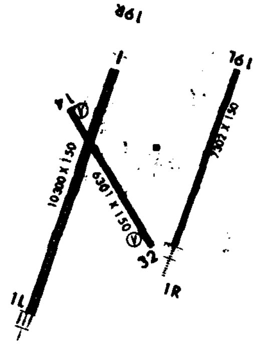
ST. LOUIS (STL)



Dependent Parallels	Independent Parallels	Dependent Converging	Independent Converging	T. iples	Separate Short Runway
30R,30L(1300')		24,30L	24,30R		24,30L

Remarks: - None

WICHITA (ICT)

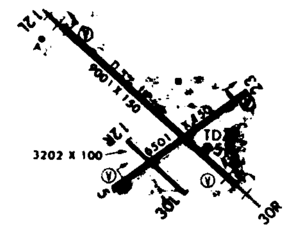


Dependent Parallels	Independent Parallels	Dependent Converging	Independent Converging	Triples	Separate Short Runway
			14,19L		

Remarks: - Runway 14 does not have ILS.
- New taxiways and/or exits may be necessary to avoid surface traffic problems.

TABLE A-2
(Continued)

DES MOINES (DSM)



Dependent Parallels	Independent Parallels	Dependent Converging	Independent Converging	Triples	Separate Short Runway
		5,12L			5,12L

Remarks: - Runway 5 does not have ILS.
- New taxiways and/or exits may be necessary to avoid surface traffic problems.

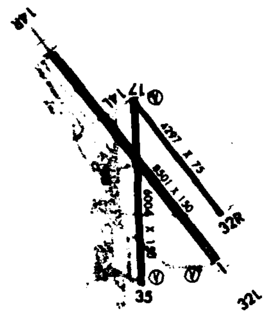
KANSAS CITY (MCI)

Dependent Parallels	Independent Parallels	Dependent Converging	Independent Converging	Triples	Separate Short Runway
			19,27		

Remarks: - Planned new runway (6500') located east of and parallel to runway 1/19 to be completed in 1988. Potential for additional converging application.

TABLE A-2
(Concluded)

OMAHA (OMA)



Dependent Parallels	Independent Parallels	Dependent Converging	Independent Converging	Triples	Separate Short Runway
32L,32R(1200') 14L,14R(1200')		17,14R			17,14R 32L,32R 14R,14L

Remarks: - None

SPIRIT OF ST. LOUIS (SUS)

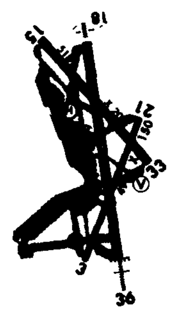
Dependent Parallels	Independent Parallels	Dependent Converging	Independent Converging	Triples	Separate Short Runway

Remarks: - No applications.

TABLE A-3
EASTERN REGION

TABLE A-3
(Continued)

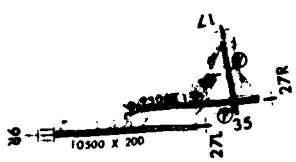
WASHINGTON NATIONAL (DCA)



Dependent Parallels	Independent Parallels	Dependent Converging	Independent Converging	Triples	Separate Short Runway
		36,33			

Remarks: - None

PHILADELPHIA (PHL)

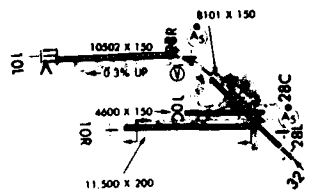


Dependent Parallels	Independent Parallels	Dependent Converging	Independent Converging	Triples	Separate Short Runway
9L,9R(1400')		17,19L	17,9R		9L,17

Remarks: - None

TABLE A-3
(Continued)

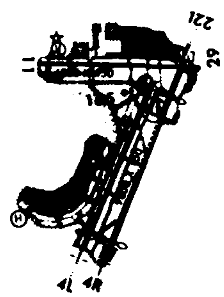
PITTSBURGH (PIT)



Dependent Parallels	Independent Parallels	Dependent Converging	Independent Converging	Triples	Separate Short Runway
10R,10C(1200')		14,10C 10R,14		10L,10C,10R	10R,14

Remarks: - None

NEWARK (EWR)

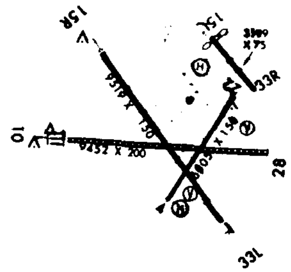


Dependent Parallels	Independent Parallels	Dependent Converging	Independent Converging	Triples	Separate Short Runway
		11,4R	11,4L		

Remarks: - None

TABLE A-3
(Continued)

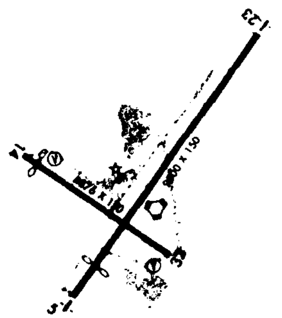
BALTIMORE (BWI)



Dependent Parallels	Independent Parallels	Dependent Converging	Independent Converging	Triples	Separate Short Runway
		15R,10			15R,10
		15R,22			15R,22
		33L,28			33L,28

Remarks: - None

NORFOLK (ORF)

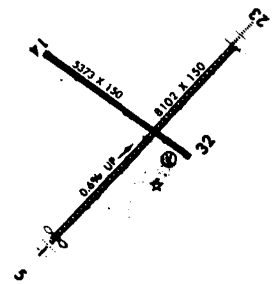


Dependent Parallels	Independent Parallels	Dependent Converging	Independent Converging	Triples	Separate Short Runway
		14,23			14,23
		32,23			32,23

Remarks: - None

TABLE A-3
(Continued)

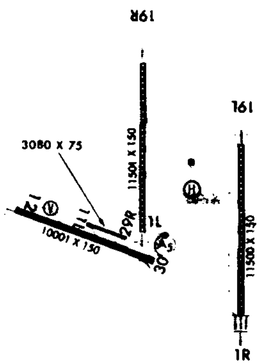
BUFFALO (BUF)



Dependent Parallels	Independent Parallels	Dependent Converging	Independent Converging	Triples	Separate Short Runway
		14,5			14,5

Remarks: - None

WASHINGTON DULLES (IAD)

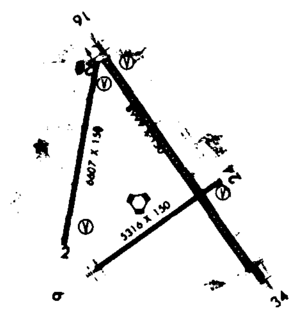


Dependent Parallels	Independent Parallels	Dependent Converging	Independent Converging	Triples	Separate Short Runway
			12,19L 12,19R	12,19R,19L	

Remarks: - None

TABLE A-3
(Continued)

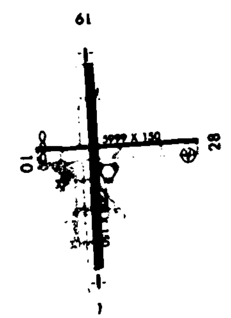
RICHMOND BYRD INT'L (RIC)



Dependent Parallels	Independent Parallels	Dependent Converging	Independent Converging	Triples	Separate Short Runway
		15,6 33,6	2,33 20,24		15,6 33,6

Remarks: - None

ALBANY (ALB)

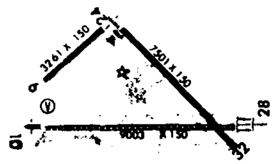


Dependent Parallels	Independent Parallels	Dependent Converging	Independent Converging	Triples	Separate Short Runway
		28,1			28,1

Remarks: - None

TABLE A-3
(Concluded)

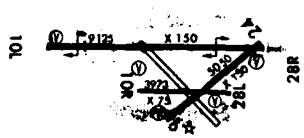
SYRACUSE (SYR)



Dependent Parallels	Independent Parallels	Dependent Converging	Independent Converging	Triples	Separate Short Runway
		10,14			10,14

Remarks: - None

NIAGARA FALLS (IAG)



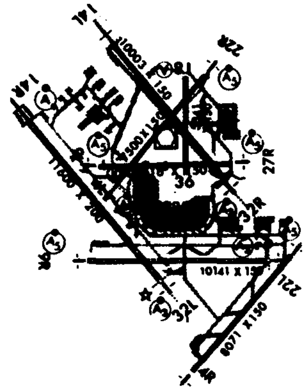
Dependent Parallels	Independent Parallels	Dependent Converging	Independent Converging	Triples	Separate Short Runway
		28R,32 10L,6			28R,32 10L,6

Remarks: - None

TABLE A-4
GREAT LAKES REGION

TABLE A-4
(Continued)

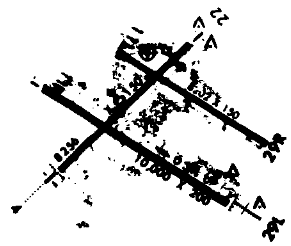
CHICAGO O'HARE (ORD)



Dependent Parallels	Independent Parallels	Dependent Converging	Independent Converging	Triples	Separate Short Runway
			22R,27L	9L,9R,4R	
			32L,27R	27L,27R,22R	
			9L,4R	22L,22R,14R	
			9R,4R		
			9R,14L		

Remarks: - None

MINNEAPOLIS (MSP)

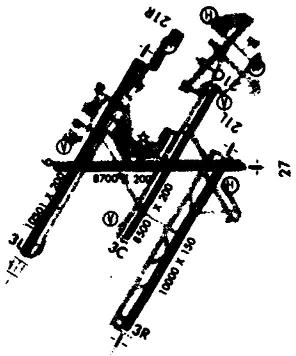


Dependent Parallels	Independent Parallels	Dependent Converging	Independent Converging	Triples	Separate Short Runway
	11R,11L(3380')	22,29L			22,29L
	29R,29L(3380')				

Remarks: - Runway 11L does not have ILS

TABLE A-4
(Continued)

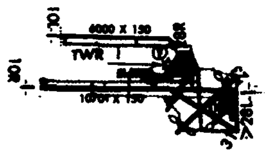
DETROIT (DTW)



Dependent Parallels	Independent Parallels	Dependent Converging	Independent Converging	Triples	Separate Short Runway
3C,3R(2000')	3L,3C(3800')		3R,9 21R,27	3R,3C,3L	

Remarks:
- Runways 3C and 9 do not have ILS.
- New runway 9R/27L planned. Potential for independent converging approaches to 21R, 27L.

COLUMBUS (CMH)

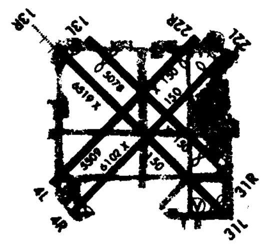


Dependent Parallels	Independent Parallels	Dependent Converging	Independent Converging	Triples	Separate Short Runway
10L,10R(2800')			28R,31 5,10L		28R,31

Remarks:
- Runways 5, 28R, and 31 do not have ILS.

TABLE A-4
(Continued)

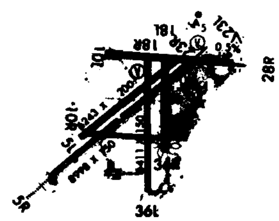
CHICAGO MIDWAY (MDW)



Dependent Parallels	Independent Parallels	Dependent Converging	Independent Converging	Triples	Separate Short Runway

Remarks: - No applications.

CLEVELAND (CLE)

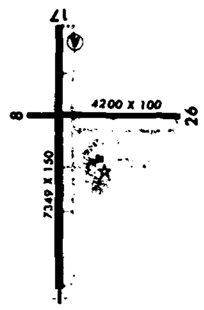


Dependent Parallels	Independent Parallels	Dependent Converging	Independent Converging	Triples	Separate Short Runway
		10L,5L 10L,5R			10L,5L 5R,10L

Remarks: - Runway 10L does not have ILS.

TABLE A-4
(Continued)

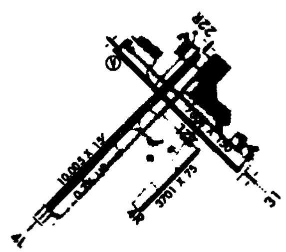
GRAND FORKS, ND (GFK)



Dependent Parallels	Independent Parallels	Dependent Converging	Independent Converging	Triples	Separate Short Runway
		26,35			26,35

Remarks: - None

INDIANAPOLIS (IND)

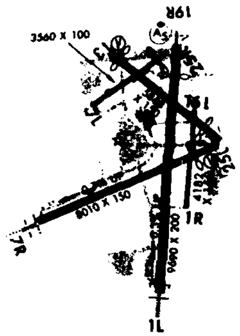


Dependent Parallels	Independent Parallels	Dependent Converging	Independent Converging	Triples	Separate Short Runway
		4L,31 13,4L			4L,31 13,4L

Remarks: - Planned new runway 4R/22L (7500') located 3500 ft. from runway 4L/22R. Potential for independent parallel approaches to 4L, 4R and 22L, 22R.

TABLE A-4
(Continued)

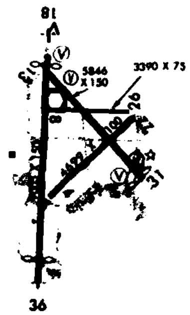
MILWAUKEE (MKE)



Dependent Parallels	Independent Parallels	Dependent Converging	Independent Converging	Triples	Separate Short Runway
1L,1R(1000')		7R,1L	13,7R		13,7R

Remarks: - None

MADISON (MSN)

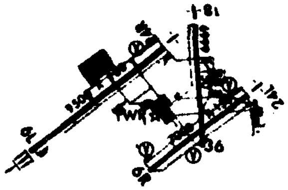


Dependent Parallels	Independent Parallels	Dependent Converging	Independent Converging	Triples	Separate Short Runway
		36,31	18,22		36,31 18,22

Remarks: - Runways 22 and 31 do not have ILS.

TABLE A-4
(Continued)

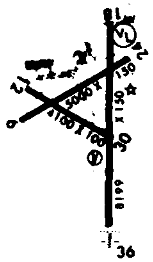
DAYTON (DAY)



Dependent Parallels	Independent Parallels	Dependent Converging	Independent Converging	Triples	Separate Short Runway
		18,24L	6L,36		18,24L

Remarks: - Runway 36 does not have ILS.

ROCKFORD, IL (RFD)

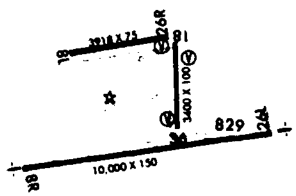


Dependent Parallels	Independent Parallels	Dependent Converging	Independent Converging	Triples	Separate Short Runway
		36,6 18,12			36,6 18,12

Remarks: - Runways 6, 12, and 18 do not have ILS.

TABLE A-4
(Continued)

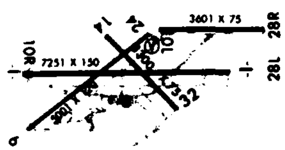
GRAND RAPIDS, MI (GRR)



Dependent Parallels	Independent Parallels	Dependent Converging	Independent Converging	Triples	Separate Short Runway

Remarks: - No applications.

LANSING, MI (LAN)

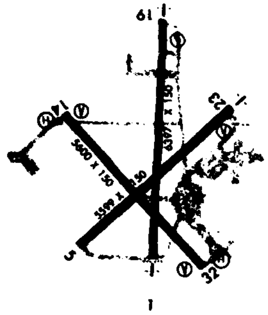


Dependent Parallels	Independent Parallels	Dependent Converging	Independent Converging	Triples	Separate Short Runway

Remarks: - No applications.

TABLE A-4
(Concluded)

AKRON CANTON, OH (CAK)



Dependent Parallels	Independent Parallels	Dependent Converging	Independent Converging	Triples	Separate Short Runway
		14,19			14,19

Remarks: - Runway 14 does not have ILS.

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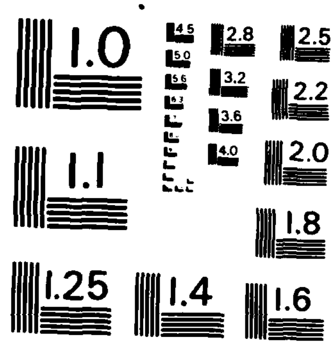
TABLE A-5

NEW ENGLAND REGION

AD-A161 155 POTENTIAL APPLICATIONS OF MULTIPLE INSTRUMENT APPROACH CONCEPTS AT 101 US AIRPORTS(U) MITRE CORP MCLEAN VA A C SILVA ET AL. SEP 85 MTR-85W65 FAA-DL5-85-2 2/2

UNCLASSIFIED DTFA01-84-C-00001 F/G 1/5 NL

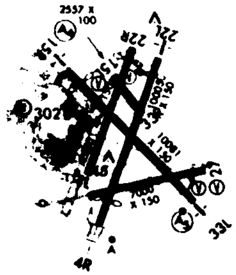
END
FILMED
DTIC



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

TABLE A-5
(Continued)

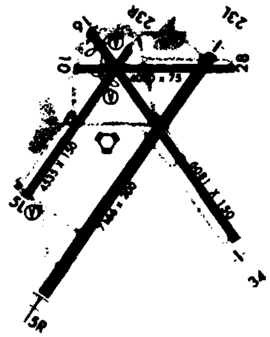
BOSTON LOGAN (BOS)



Dependent Parallels	Independent Parallels	Dependent Converging	Independent Converging	Triples	Separate Short Runway
22R,22L(1500')		4R,33L			4R,33L

Remarks: - None

PROVIDENCE (PVD)



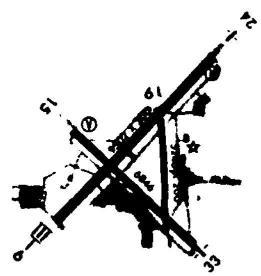
Dependent Parallels	Independent Parallels	Dependent Converging	Independent Converging	Triples	Separate Short Runway
5L,5R(1700')		34,5R 28,34			34,5R 28,34

Remarks: - Runway 10/28 is scheduled to be closed and be used as a taxiway.

TABLE A-5
NEW ENGLAND REGION

TABLE A-5
(Continued)

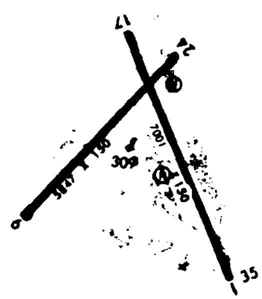
WINDSOR LOCKS (BDL)



Dependent Parallels	Independent Parallels	Dependent Converging	Independent Converging	Triples	Separate Short Runway
		24,33 6,1			24,33 6,1

Remarks: - None

MANCHESTER, NH (MHT)

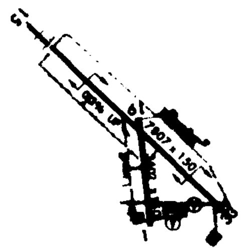


Dependent Parallels	Independent Parallels	Dependent Converging	Independent Converging	Triples	Separate Short Runway
		35,6			35,6

Remarks: - None

TABLE A-5
(Concluded)

BURLINGTON (BTV)	Dependent Parallels	Independent Parallels	Dependent Converging	Independent Converging	Triples	Separate Short Runway

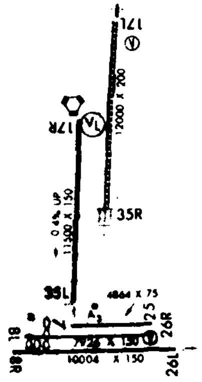


Remarks: - No applications.

TABLE A-6
NORTHWEST-MOUNTAIN REGION

TABLE A-6
(Continued)

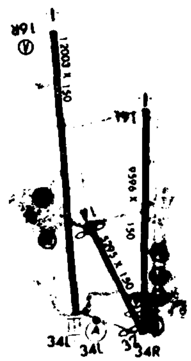
DENVER (DEN)



Dependent Parallels	Independent Farallels	Dependent Converging	Independent Converging	Triples	Separate Short Runway
17R,17L(1600')			17L,26L		

Remarks: - None

SALT LAKE CITY (SLC)



Dependent Parallels	Independent Parallels	Dependent Converging	Independent Converging	Triples	Separate Short Runway
	16L,16R(3500')		14,16L 34L,32		14,16L 34L,32

Remarks: - Airspace and terrain may create problems to converging operations.

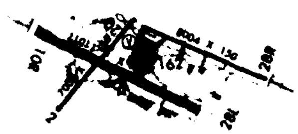
TABLE A-6
(Continued)

SEATTLE (SEA)

Dependent Parallels	Independent Parallels	Dependent Converging	Independent Converging	Triples	Separate Short Runway

Remarks: - No applications.

PORTLAND (PDX)



Dependent Parallels	Independent Parallels	Dependent Converging	Independent Converging	Triples	Separate Short Runway
	28L,28R(3100')	10R,2 28L,2			2,28L

Remarks: - Runway 28L does not have ILS.
- Restrictions due to noise abatement procedures.

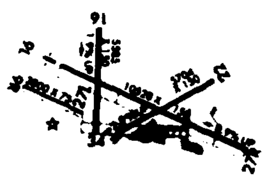
TABLE A-6
(Continued)

BOISE (BOI)

Dependent Parallels	Independent Parallels	Dependent Converging	Independent Converging	Triples	Separate Short Runway

Remarks: - No applications.

BILLINGS, MT (BIL)

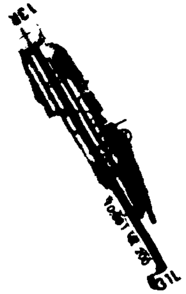


Dependent Parallels	Independent Parallels	Dependent Converging	Independent Converging	Triples	Separate Short Runway
		34,27R	16,22		16,22 34,27R

Remarks: - None

TABLE A-6
(Concluded)

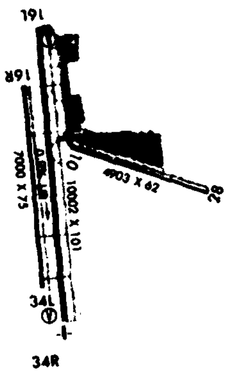
BOEING FIELD (BFI)



Dependent Parallels	Independent Parallels	Dependent Converging	Independent Converging	Triples	Separate Short Runway

Remarks: - No applications.

CENTENNIAL, CO (APA)



Dependent Parallels	Independent Parallels	Dependent Converging	Independent Converging	Triples	Separate Short Runway

Remarks: - No applications.

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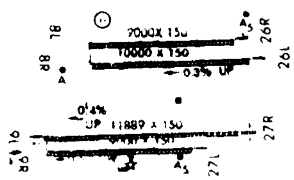
TABLE A-7
SOUTHERN REGION

TABLE A-7
(Continued)

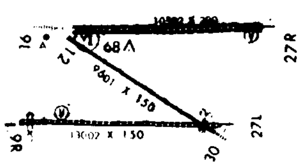
ATLANTA (ATL)



Dependent Parallels	Independent Parallels	Dependent Converging	Independent Converging	Triples	Separate Short Runway
8L,8R(1000') 9L,9R(1000')				8,9R,9L	

Remarks: - All runways will have ILS by mid 1985.
- MLS scheduled for 1988 on both ends of 9R/17L.

MIAMI (MIA)

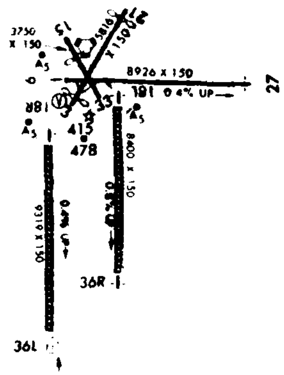


Dependent Parallels	Independent Parallels	Dependent Converging	Independent Converging	Triples	Separate Short Runway
		12,9R	27R,30		

Remarks: - None

TABLE A-7
(Continued)

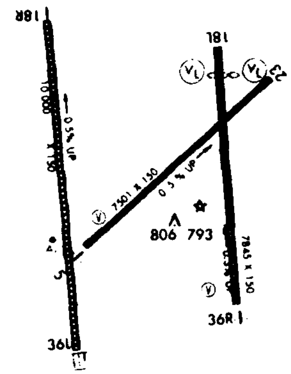
MEMPHIS (MEM)



Dependent Parallels	Independent Parallels	Dependent Converging	Independent Converging	Triples	Separate Short Runway
	36L,36R(3400') 18L,18R(3400')	21,27	36L,27 36R,27 36R,3 21,18R		21,27

Remarks: - Runways 3 and 21 do not have ILS.

CHARLOTTE (CLT)

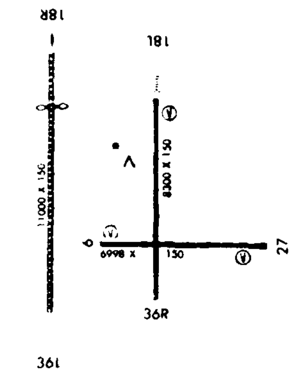


Dependent Parallels	Independent Parallels	Dependent Converging	Independent Converging	Triples	Separate Short Runway
		5,36R	18R,23		5,36R

Remarks: - Runway 23 does not have ILS.
- Extension of runway 5 by 2750 ft. could allow independent converging approaches to 5, 36R.

TABLE A-7
(Continued)

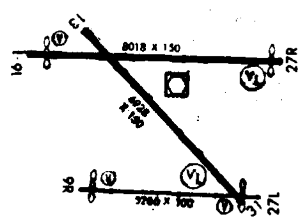
TAMPA (TPA)



Dependent Parallels	Independent Parallels	Dependent Converging	Independent Converging	Triples	Separate Short Runway
		27,18L	27,18R		27,18L

Remarks: - Runway 27 does not have ILS.

FORT LAUDERDALE (FLL)

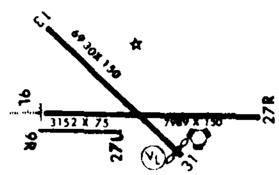


Dependent Parallels	Independent Parallels	Dependent Converging	Independent Converging	Triples	Separate Short Runway
	27L,27R(4000') 9L,9R(4000')	27R,31			27L,27R 9L,9R 27R,31

Remarks: - Runways 9R, 27L, and 31 do not have ILS.

TABLE A-7
(Continued)

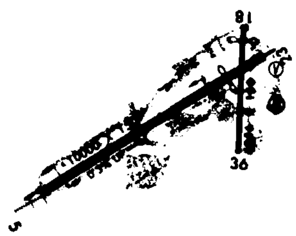
WEST PALM BEACH (PBI)



Dependent Parallels	Independent Parallels	Dependent Converging	Independent Converging	Triples	Separate Short Runway
		9L,13			9L,13

Remarks: - Runway 13 does not have ILS.

BIRMINGHAM (BHM)

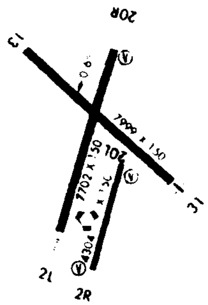


Dependent Parallels	Independent Parallels	Dependent Converging	Independent Converging	Triples	Separate Short Runway

Remarks: - No applications.

TABLE A-7
(Continued)

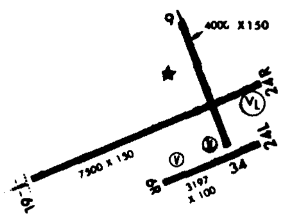
NASHVILLE (BNA)



Dependent Parallels	Independent Parallels	Dependent Converging	Independent Converging	Triples	Separate Short Runway
2L,2R(1800')		31,2L	31,2R		31,2L 31,2R

Remarks: - None

DAYTONA BEACH (DAB)

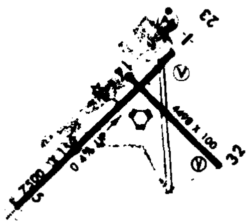


Dependent Parallels	Independent Parallels	Dependent Converging	Independent Converging	Triples	Separate Short Runway
		16,6L			16,6L

Remarks: - Runway 16 does not have ILS.

TABLE A-7
(Continued)

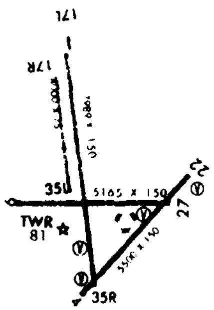
RALEIGH (RDU)



Dependent Parallels	Independent Parallels	Dependent Converging	Independent Converging	Triples	Separate Short Runway
		32,5			32,5

Remarks: - Runway 32 does not have ILS.
- New runway 5L/23R under construction 3500 ft. north and parallel to runway 5/23 (operational December 1985). Potential for independent parallel approaches to 5L, 5R and 23L, 23R and independent converging approaches to 5L, 32.

ST. PETERSBURG (PIE)

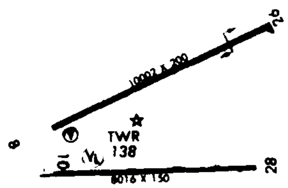


Dependent Parallels	Independent Parallels	Dependent Converging	Independent Converging	Triples	Separate Short Runway
		22,17L 4,9			22,17L 4,9

Remarks: - Runways 4, 9, and 22 do not have ILS.

TABLE A-7
(Continued)

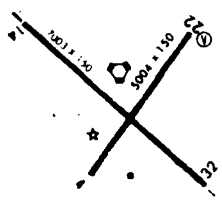
SAN JUAN, PR (SJU)



Dependent Parallels	Independent Parallels	Dependent Converging	Independent Converging	Triples	Separate Short Runway
			25,28		

Remarks: - None

SARASOTA (SRQ)

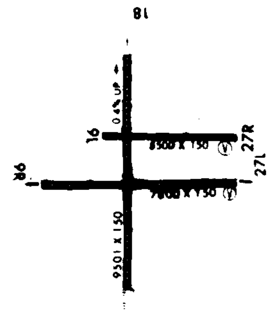


Dependent Parallels	Independent Parallels	Dependent Converging	Independent Converging	Triples	Separate Short Runway

Remarks: - No applications.

TABLE A-7
(Continued)

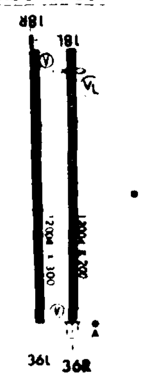
CINCINNATI (CVG)



Dependent Parallels	Independent Parallels	Dependent Converging	Independent Converging	Triples	Separate Short Runway
27R,27L(1700')		27L,36 18,27L			36,27L 18,27L 27R,27L

Remarks: - None

ORLANDO (MCO)

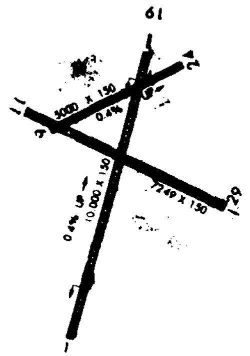


Dependent Parallels	Independent Parallels	Dependent Converging	Independent Converging	Triples	Separate Short Runway
18L,18R(1600')					

Remarks: - None

TABLE A-7
(Continued)

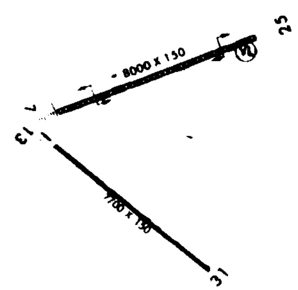
LOUISVILLE, KY (SDF)



Dependent Parallels	Independent Parallels	Dependent Converging	Independent Converging	Triples	Separate Short Runway
		29,24 6,1			29,24 6,1

Remarks: - Runways 6 and 24 do not have ILS.

JACKSONVILLE (JAX)

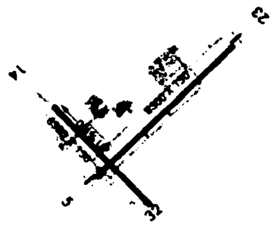


Dependent Parallels	Independent Parallels	Dependent Converging	Independent Converging	Triples	Separate Short Runway
			31,25		

Remarks: - None

TABLE A-7
(Continued)

GREENSBORO, NC (GSO)



Dependent Parallels	Independent Parallels	Dependent Converging	Independent Converging	Triples	Separate Short Runway
		14,23 32,23			14,23 32,23

Remarks: - None

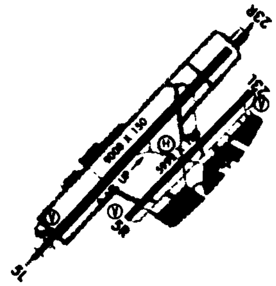
CHARLESTON, SC (CHS)

Dependent Parallels	Independent Parallels	Dependent Converging	Independent Converging	Triples	Separate Short Runway
		33,3			33,3

Remarks: - None

TABLE A-7
(Concluded)

KNOXVILLE (TYS)



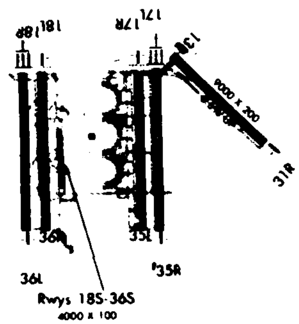
Dependent Parallels	Independent Parallels	Dependent Converging	Independent Converging	Triples	Separate Short Runway
5L,5R(1200')					5L,5R

Remarks: - Runway 5R does not have ILS.

TABLE A-8
SOUTHWEST REGION

TABLE A-8
(Continued)

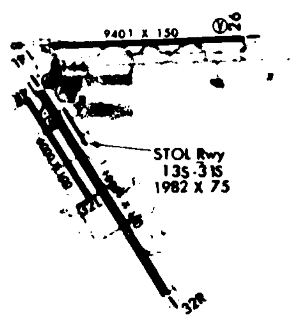
DALLAS/FT. WORTH (DFW)



Dependent Parallels	Independent Parallels	Dependent Converging	Independent Converging	Triples	Separate Short Runway
			35L,31R 35R,31R 36L,31R 36R,31R	35L/R,36L/R,31R	

Remarks:
- Runways 35L and 36R do not have ILS.
- Environmental restriction on runway 31R.
- New runway 13R/31L to be constructed on June 1986. Potential for additional parallel or converging applications.

HOUSTON (IAH)

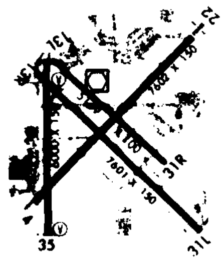


Dependent Parallels	Independent Parallels	Dependent Converging	Independent Converging	Triples	Separate Short Runway
			26,32R		

Remarks:
- New runway 9R/27L to be constructed parallel to and south of runway 8/26 (1986).
- New runway 8L/26R to be constructed parallel to and north of runway 8/26 (1996).
- New runway 9L/27R to be constructed parallel to and south of runway 8/26 (2000).
- Potential for additional applications with each new runway.

TABLE A-8
(Continued)

HOUSTON HOBBY (HOU)



Dependent Parallels	Independent Parallels	Dependent Converging	Independent Converging	Triples	Separate Short Runway
		17,22			17,22
		22,31L			22,31L

Remarks: - ILS scheduled for runway 22.
- Airspace restrictions.

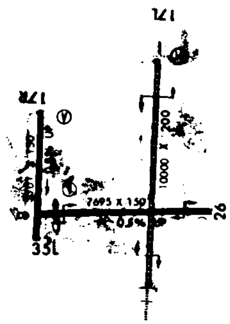
DALLAS LOVE (DAL)

Dependent Parallels	Independent Parallels	Dependent Converging	Independent Converging	Triples	Separate Short Runway
31L,31R(2975')					
13R,13L(2975')					

Remarks: - Separation between runways 31 and 13 falls 25 ft. short of independent parallel defintion.
- Runways 31 and 13 will have ILS or MLS by June 1986.

TABLE A-8
(Continued)

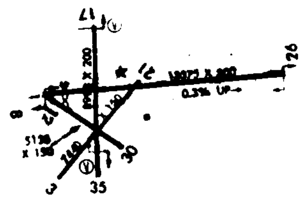
TULSA (TUL)



Dependent Parallels	Independent Parallels	Dependent Converging	Independent Converging	Triples	Separate Short Runway
		17R,26			17R,26

Remarks: - Runway 26 does not have ILS.
- New taxiways and/or exits may be necessary to avoid surface traffic problems.

ALBUQUERQUE (ABQ)

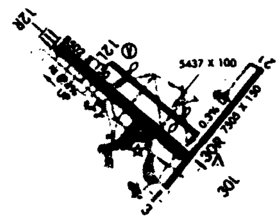


Dependent Parallels	Independent Parallels	Dependent Converging	Independent Converging	Triples	Separate Short Runway

Remarks: - No applications.

TABLE A-8
(Continued)

SAN ANTONIO (SAT)



Dependent Parallels	Independent Parallels	Dependent Converging	Independent Converging	Triples	Separate Short Runway
		12R,21			12R,21

Remarks:
- Runway 21 does not have ILS.
- Airspace restriction due to Randolf AFB. (MLS on runway 21 may be solution.)

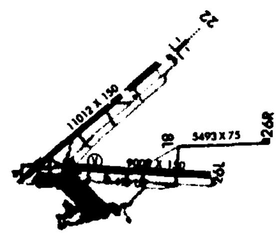
AUSTIN (AUS)

Dependent Parallels	Independent Parallels	Dependent Converging	Independent Converging	Triples	Separate Short Runway
		31L,35L			31L,35L

Remarks:
- Runway 35L does not have ILS.
- Airspace restrictions.

TABLE A-8
(Continued)

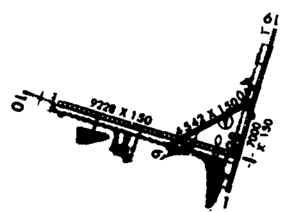
EL PASO (ELP)



Dependent Parallels	Independent Parallels	Dependent Converging	Independent Converging	Triples	Separate Short Runway
26L,26R(1200')			22,26R 22,26L		22,26R 22,26L

Remarks: - Runways 26 do not have ILS.
- Airspace restrictions due to Biggs AAF and international border.

NEW ORLEANS (MSY)

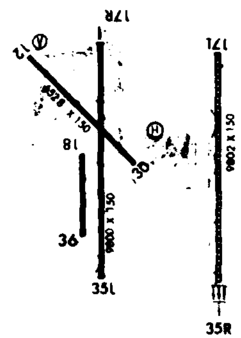


Dependent Parallels	Independent Parallels	Dependent Converging	Independent Converging	Triples	Separate Short Runway
			10,19		

Remarks: - Runway 19 does not have ILS.
- Noise restrictions on runway 19.

TABLE A-8
(Continued)

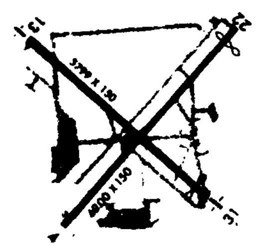
OKLAHOMA CITY (OKC)



Dependent Parallels	Independent Parallels	Dependent Converging	Independent Converging	Triples	Separate Short Runway
			12,17L		

Remarks: - Runway 12 does not have ILS.
- May conflict with departures from PWA airport.

BATON ROUGE (BTR)

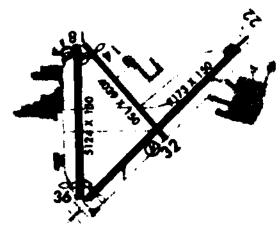


Dependent Parallels	Independent Parallels	Dependent Converging	Independent Converging	Triples	Separate Short Runway

Remarks: No applications.

TABLE A-8
(Continued)

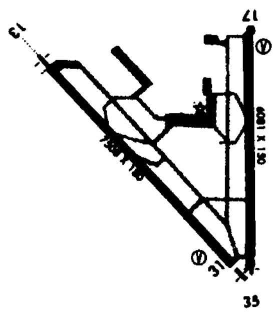
LITTLE ROCK (LIT)



Dependent Parallels	Independent Parallels	Dependent Converging	Independent Converging	Triples	Separate Short Runway
			18,22		18,22

Remarks:
- Hilly terrain off runway 18; possible obstacles.
- Restrictions due to other airports.
- New runway 22L under construction on east side of airport. Potential for parallel and/or converging applications.

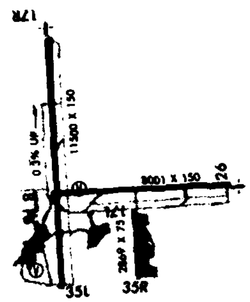
CORPUS CHRISTI (CRP)



Dependent Parallels	Independent Parallels	Dependent Converging	Independent Converging	Triples	Separate Short Runway
			13,17		13,17

Remarks:
- Runway 17 does not have ILS.
- New taxiways and/or exits may be necessary to avoid surface traffic problems.
- New runways 13R/31L and 17R/35L to be constructed in 10 years. Potential for additional parallel and/or converging applications.

LUBBOCK (LBB)



Dependent Parallels	Independent Parallels	Dependent Converging	Independent Converging	Triples	Separate Short Runway
		17R,26 35L,26			17R,26 35L,26

Remarks: - Runways 17R and 35L do not have ILS.
- New taxiways and/or exits may be necessary to avoid surface traffic problems.

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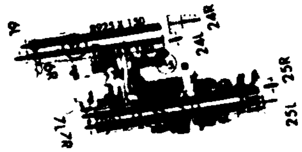
TABLE A-9
WESTERN-PACIFIC REGION

TABLE A-9
(Continued)

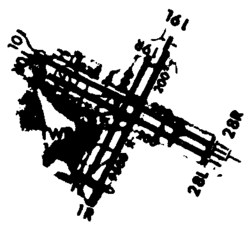
LOS ANGELES (LAX)



Dependent Parallels	Independent Parallels	Dependent Converging	Independent Converging	Triples	Separate Short Runway

Remarks: - No applications.

SAN FRANCISCO (SFO)

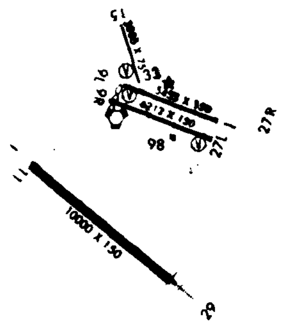


Dependent Parallels	Independent Parallels	Dependent Converging	Independent Converging	Triples	Separate Short Runway
		10L,1R 28R,1R			10L,1R 28R,1R

Remarks: - Runway 1R does not have ILS.
- New taxiways and exits may be necessary to avoid surface traffic problems.

TABLE A-9
(Continued)

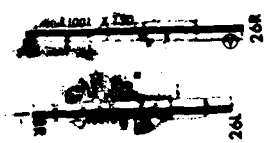
OAKLAND (OAK)



Dependent Parallels	Independent Parallels	Dependent Converging	Independent Converging	Triples	Separate Short Runway
27L,27R(1000')			29,27L 29,27R		29,27R

Remarks:
- New taxiways and exits may be necessary to avoid surface traffic problems.
- Restrictions due to other airports and/or noise.

PHOENIX (PHX)

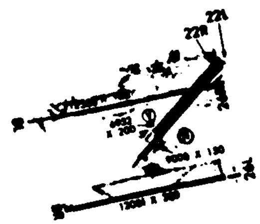


Dependent Parallels	Independent Parallels	Dependent Converging	Independent Converging	Triples	Separate Short Runway
	8R,8L(3400') 26R,26L(3400')				

Remarks:
- All runways will have ILS or MLS by 1986.
- New taxiways and/or exits may be necessary to avoid surface traffic problems.
- Restrictions due to other airports and/or noise.

TABLE A-9
(Continued)

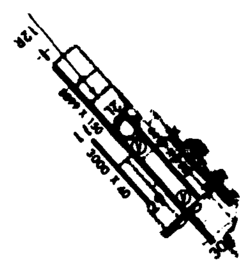
HONOLULU (HNL)



Dependent Parallels	Independent Parallels	Dependent Converging	Independent Converging	Triples	Separate Short Runway
		8L,4R			8L,4R

Remarks: - New taxiways and/or exits may be necessary to avoid surface traffic problems.
- Restrictions due to other airports and/or noise.

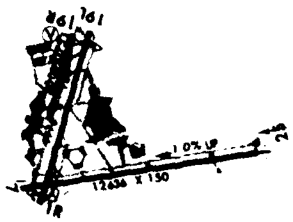
SAN JOSE (SJC)



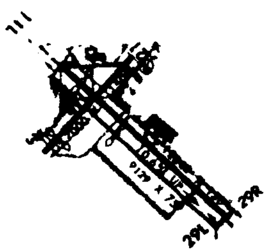
Dependent Parallels	Independent Parallels	Dependent Converging	Independent Converging	Triples	Separate Short Runway

Remarks: - No applications.

TABLE A-9
(Continued)

LAS VEGAS (LAS)	Dependent Parallels	Independent Parallels	Dependent Converging	Independent Converging	Triples	Separate Short Runway
			19R,25			19R,25

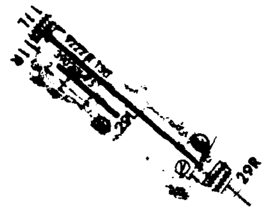
Remarks: - Runway 19R does not have ILS.
- It is possible to build a new runway 7R/25L. Potential application of parallel and/or converging approaches.

TUCSON (TUS)	Dependent Parallels	Independent Parallels	Dependent Converging	Independent Converging	Triples	Separate Short Runway
						

Remarks: - No applications.

TABLE A-9
(Continued)

FRESNO (FAT)



Dependent Parallels	Independent Parallels	Dependent Converging	Independent Converging	Triples	Separate Short Runway

Remarks: - No applications.

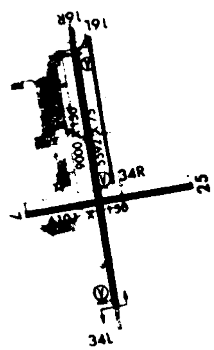
BURBANK (BUR)

Dependent Parallels	Independent Parallels	Dependent Converging	Independent Converging	Triples	Separate Short Runway
		7,15			7,15

Remarks:
- Runway 15 does not have ILS. An MLS is scheduled.
- New taxiways and/or exits may be necessary to avoid surface traffic problems.
- Restrictions due to other airports and/or noise.

TABLE A-9
(Continued)

RENO (RNO)



Dependent Parallels	Independent Parallels	Dependent Converging	Independent Converging	Triples	Separate Short Runway
		25,16 7,16			25,16 7,16

Remarks: - Runway 25 does not have ILS.
- New taxiways and/or exits may be necessary to avoid surface traffic problems.

SAN DIEGO (SAN)

Dependent Parallels	Independent Parallels	Dependent Converging	Independent Converging	Triples	Separate Short Runway

Remarks: - No applications.

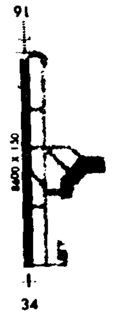
TABLE A-9
(Continued)

KAHULUI, HAWAII (HOG)

Dependent Parallels	Independent Parallels	Dependent Converging	Independent Converging	Triples	Separate Short Runway
		5,2			5,2

Remarks:
- Both runways do not have ILS.
- New taxiways and/or exits may be necessary to avoid surface traffic problems.
- Restrictions due to other airports and/or noise.

SACRAMENTO (SMF)



Dependent Parallels	Independent Parallels	Dependent Converging	Independent Converging	Triples	Separate Short Runway

Remarks:
- No applications.
- New runway 16L/34R planned (1987).

TABLE A-9
(Concluded)

	Dependent Parallels	Independent Parallels	Dependent Converging	Independent Converging	Triples	Separate Short Runway
ONTARIO (ONT)			21,26L			21,26L

Remarks: - Runway 21 does not have ILS.
- Restrictions due to other airports and/or noise.

APPENDIX B
ALPHABETICAL INDEX OF AIRPORTS FOR APPENDIX A

APPENDIX C
QUESTIONNAIRE SENT TO FAA REGIONAL OFFICES

The following is the questionnaire that was sent to each of the FAA regional offices to aid in the process of evaluating site-specific factors that could affect the applicability of the concepts. In some regions the response to the questionnaire was much more detailed and complete than in others.

Each region was provided with a description and implementation criteria for each of the concepts attached to the questionnaire. Each region was also provided with a draft list of all the potential applications of each concept in that particular region.

Converging Approaches

1. Technical Feasibility:

   a. Do both runways have ILS or MLS? If not, are they scheduled to receive one? When? Are precision approaches to these runways possible?

   b. Would simultaneous arrival streams to these runways create a surface traffic flow problem? Are existing taxiways and runway exits appropriate for this kind of operation on these runways? If not, is it possible to build new taxiways or exits?

   c. Are there any obstacles that would not allow converging approaches to these runways? Would there be any problem involving the TERPS approach surfaces?

2. Operational Feasibility:

   a. Are there any airspace restrictions that would prevent independent converging operations to these runways? If so, what are they?

   b. Are there any restrictions due to factors such as other airports in the vicinity, environmental (noise), political, etc?

   c. Do the current ATC procedures for the airport allow independent IFR converging operations on these runways today?

3. Other Possibilities:

   a. Is it possible to build one or more new runways at the airport that could allow independent converging operations? If so, where would it (they) be located? Would any existing structures have to be removed or altered?

   b. Are there any possible applications of independent converging runways using existing concrete at that airport, other than those listed in Table 1*?

---

* Table 1 consisted of a draft list of all potential applications at each airport identified by the authors. Table 1 was sent attached to this questionnaire.

c. Are there any possible procedures that would allow independent converging operations to runways where it is not possible under current procedures?

4. Relation to Airport Master Plan:

a. Are there any planned runways? If so, where and when will they be built?

b. Could planned runways (if any) be suitable for independent converging operations?

c. Would planned runways (if any) interfere with independent converging applications listed in Table 1? Are there any other structures planned (tower, terminals, etc.) that would interfere?

5. Potential Benefits:

a. Would independent converging runways increase the capacity of that airport presently? In the future (with a different demand and maybe a different mix of aircraft)?

Parallel Approaches

1. Technical Feasibility:

a. Do both runways have ILS or MLS? If not, are they scheduled to receive one? When? Are precision approaches to these runways possible?

b. Does the separation between runway centerlines comply with the definition of independent parallel runways?

c. Would simultaneous arrival streams to these runways create a surface traffic flow problem? Are existing taxiways and runway exits appropriate for simultaneous operations on these runways? If not, is it possible to build new taxiways or exits?

d. Are there any obstacles that would not allow simultaneous approaches to these runways? Would there be any problem involving the approach surfaces?

2. Operational Feasibility:

a. Are there any airspace restrictions that would prevent simultaneous operations to these runways? If so, what are they?

b. Are there any restrictions due to factors such as other airports in the vicinity, environmental, political, etc.?

3. Other Possibilities:

a. Is it possible to build any other parallel runway at the airport which is at least 4000 feet long? If so, where would it be built? Would any existing structures have to be removed or altered?

b. Are there any possible applications of independent parallels using existing concrete at that airport, other than those listed in Table 1?

c. Are there any possible procedures that could allow independent (simultaneous) parallel approaches to runways where it is not possible under current procedures?

4. Relation to Airport Master Plan:

a. Are there any planned runways? If so, where and when will they be built?

b. Could planned runways (if any) be suitable for simultaneous parallel operations?

c. Would planned runways (if any) interfere with independent parallel applications listed in Table 1? Are there any other structures planned (towers, terminals, etc.) that would interfere?

5. Potential Benefits:

a. Would independent parallel runways presently increase the capacity of that airport? In the future (with a different demand and maybe a different mix of aircraft)?

Separate Short Runways

1. Technical Feasibility:

a. Do both runways have ILS or MLS? If not, are they scheduled to receive one? When? Are precision approaches to these runways possible?

b. Does the runway have the required dimensions?

c. Would simultaneous arrival streams to these runways create a surface traffic flow problem? Are existing taxiways and runway exits appropriate for this kind of operation on these runways? If not, is it possible to build new taxiways or exits?

d. Are the general aviation apron and terminal easily accessible from this short runway? If not, can they be relocated?

e. Are there any obstacles that would not allow independent operation of this short runway? Would there be any problems involving the approach surfaces?

2. Operational Feasibility:

a. Are there any airspace restrictions that would prevent the use of a separate short runway? If so, what are they?

b. Are there any other restrictions due to factors such as other airports in the vicinity, environmental, political, etc.?

c. Do the current ATC procedures for that airport allow the use of separate short runways during IMC?

d. About what percent of the current IFR traffic could use a separate short runway (percent of GA, commuter)?

3. Other Possibilities:

a. If a new separate short runway were to be built at this airport, where would the ideal location be? What structures would have to be removed or relocated to build this short runway and operate it in IMC?

b. Are there any possible applications of separate short runways using existing concrete, other than those listed in Table 1?

c. Are there any procedures that would allow operations on a separate short runway where it is not possible under current procedures?

4. <u>Relation to Airport Master Plan</u>:

a. Are there any planned runways? If no, where and when will they be built?

b. Could planned runways (if any) be suitable for the application of the separate short runway concept?

c. Would planned runways (if any) interfere with the separate short runway operations listed in Table 1? Are there any other structures planned (towers, terminals, etc.) that would interfere?

5. <u>Potential Benefits</u>:

a. Would a separate short runway increase the capacity at that airport presently? In the future (with a different demand and maybe a different mix of aircraft)?

APPENDIX D
INPUTS FOR DELAY SAVINGS ESTIMATIONS

This appendix presents the inputs for calculating capacity and the demand profiles at each of the airports for which the delay savings were calculated in Section 4. These delay savings result from the application of the multiple IFR arrival stream concepts.

D.1 Inputs for Capacity Calculation

The inputs to the Upgraded FAA Airfield Capacity Model, which performs the capacity calculations, are shown in Tables D-1, D-2, and D-3. These tables contain Runway Occupancy Times (ROTs), fleet mixes, and approach speeds and interarrival separations respectively.

D.2 Daily Demand Profiles

Table D-4 presents the hourly arrival demand at each of the airports studied. These profiles were constructed following the methodology described in section 4.1.2. These demand profiles along with the airports capacities were used to evaluate the delays at each airport.

TABLE D-1
RUNWAY OCCUPANCY TIMES[1] (Seconds)

	Aircraft Type			
Airport	Class A	Class B	Class C	Class D
	Small Prop < 12,500 lb.	Large Prop > 12,500 lb.	Large Jet 12,500 lb. to 300,000 lb.	Heavy Jet > 300,000 lb.
BOS	48	50	52	57
DFW	40	45	50	55
EWR	40	41	42	46
IAH	40	45	50	55
JFK	40	45	50	55
MEM	40	45	50	55
PHL	40	45	50	55

1 - With exception of BOS and EWR, the values of ROT used are nominal values.

TABLE D-2
FLEET MIXES (%)

Airport	Class A Small Prop < 12,500 lb.	Class B Large Prop > 12,500 lb.	Class C Large Jet 12,500 lb. to 300,000 lb.	Class D Heavy Jet > 300,000 lb.
BOS	21%	28%	43%	8%
DFW	10	18	65	7
EWR	24	18	45	13
IAH	30	14	50	6
JFK	15	12	32	41
MEM	52	11	36	1
PHL	29	31	33	7

TABLE D-3
APPROACH SPEEDS AND ARRIVAL-ARRIVAL SEPARATIONS[1]

	Aircraft Type			
	Class A	Class B	Class C	Class D
	Small Prop < 12,500 lb.	Large Prop > 12,500 lb.	Large Jet 12,500 lb. to 300,000 lb.	Heavy Jet > 300,000 lb.
Approach Speed (kn)	100	120	130	140
Arrival-Arrival Separations (nmi) — Lead \ Trail				
A	3.0	3.0	3.0	3.0
B	4.0	3.0	3.0	3.0
C	4.0	4.0	3.0	3.0
D	6.0	5.0	5.0	4.0

1 - Assumed equal for all airports.

TABLE D-4
DAILY ARRIVAL DEMAND PROFILE

	Airport						
Hour	BOS	DFW	EWR	IAH	JFK	MEM	PHL
0	3	2	8	4	2	21	3
1	0	1	3	0	6	11	1
2	2	3	4	8	4	0	0
3	0	1	2	0	1	0	0
4	0	2	0	0	2	0	1
5	0	6	6	0	6	1	1
6	8	18	3	2	13	3	7
7	36	43	39	36	10	39	27
8	45	42	29	21	22	34	34
9	40	27	30	25	2	8	22
10	34	67	25	47	11	3	17
11	44	37	31	23	14	58	26
12	30	69	28	53	11	4	18
13	26	29	35	11	20	6	18
14	35	56	34	36	48	69	40
15	50	40	24	15	59	11	21
16	46	57	44	36	66	3	28
17	50	83	38	36	43	8	38
18	58	36	42	28	34	75	35
19	39	51	35	44	24	9	26
20	35	63	35	17	23	8	19
21	37	36	33	19	19	29	26
22	24	24	27	16	4	7	18
23	7	6	21	11	10	10	7

APPENDIX E
ACRONYMS

AOCI	Airport Operators Council International
ATCAC	Air Traffic Control Advisory Committee
FAA	Federal Aviation Administration
IFR	Instrument Flight Rules
ILS	Instrument Landing System
NASCOM	National Aviation System Communications
nmi	nautical miles
STOL	Short Takeoff and Landing
TERPS	Terminal Instrument Procedures
VFR	Visual Flight Rules

APPENDIX F
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